

Institute of Water Research Annual Technical Report FY 2011

Introduction

The Institute of Water Research (IWR) at Michigan State University (MSU) continuously provides timely information for addressing contemporary land and water resource issues through coordinated multidisciplinary efforts using advanced information and networking systems. The IWR endeavors to strengthen MSU's efforts in nontraditional education, outreach, and interdisciplinary studies utilizing available advanced technology, and partnerships with local, state, regional, and federal organizations and individuals. Activities include coordinating education and training programs on surface and ground water protection, land use and watershed management, and many others. We also encourage accessing our web site which offers a more comprehensive resource on IWR activities, goals, and accomplishments: <http://www.iwr.msu.edu>.

The Institute has increasingly recognized the acute need and effort for multi-disciplinary research to achieve better water management and improved water quality. This effort involves the integration of research data and knowledge with the application of models and geographic information systems (GIS) to produce spatial decision support systems (SDSS). These geospatial decision support systems provide an analytical framework and research data via the web to assist individuals and local and state government agencies make wise resource decisions. The Institute has also increasingly become a catalyst for region wide decision-making support in partnership with other states in EPA Region 5 using state-of-the-art decision support systems.

The Institute works closely with the MSU Cooperative Extension Service to conduct outreach and education. USGS support of this Institute as well as others in the region enhances the Institute credibility and facilitates partnerships with other federal agencies, universities, and local and state government agencies. The Institute also provides important support to MSU-WATER, a major university initiative dealing with urban storm water issues with funding from the university Vice President for Finance. A member of the Institute's staff works half-time in facilitating MSU-WATER activities so the Institute enjoys a close linkage with this project. The following provides a more detailed explanation of the Institute's general philosophy and approach in defining its program areas and responsibilities.

General Statement

To deal successfully with the emergence of water resource issues unique to the 21st century, transformation of our knowledge and understanding of water for the protection, conservation, and management of water resources is imperative. Radically innovative approaches involving our best scientific knowledge, extensive spatial databases, and "intelligent" tools that visualize wise resource management and conservation in a single holistic system are likewise imperative. Finally, holistic system analysis and understanding requires a strong and integrated multi-disciplinary framework.

Research Program Introduction

The management of water resources, appropriate policies, and data acquisition and modeling continue to be at the forefront of the State Legislatures agenda and numerous environmental and agricultural organizations. Our contribution to informing the debate involved numerous meetings, personal discussions, and most importantly, the enhancement of web-based information to aid in the informed decision-making process.

Unique Capabilities: Decision Support Systems as the Nexus

IWR, with its “extended research family,” is exceptionally well-positioned to integrate research conducted within each of the three principal water research domains: hydrologic sciences, water resources, and aquatic ecosystems. Integrated decision support both reflects and forms the nexus of these three research domains. Expanding web accessibility to the decision support system nexus (formed by the intersection of the three research domains) will facilitate broad distribution of science-based research produced in these domains. A special emphasis is being placed on facilitation of science-based natural resource state and national policy evolution.

The Institute’s extensive experience in regional and national networking provides exceptional opportunities for assembling multi-agency funding to support interdisciplinary water research projects and multi-university partnerships.

Using a Multi-Disciplinary Framework

Using a multi-disciplinary framework facilitates dynamic applications of information to create geospatial, place-based strategies, including watershed management tools, to optimize economic benefits and assure long-term sustainability of valuable water resources. New information technologies including GIS and computational analysis, enhanced human/machine interfaces that drive better information distribution, and access to extensive real-time environmental datasets make a new “intelligent reality” possible.

Effective watershed management requires integration of theory, data, simulation models, and expert judgment to solve practical problems. Geospatial decision support systems meet these requirements with the capacity to assess and present information geographically, or spatially, through an interface with a geographic information system (GIS). Through the integration of databases, simulation models, and user interfaces, these systems are designed to assist decision makers in evaluating the economic and environmental impacts of various watershed management alternatives.

The ultimate goal of these new imperatives is to secure and protect the future of water quality and supplies in the Great Lakes Basin and across the country and the world—with management strategies based on an understanding of the uniqueness of each watershed.

USGS Award No. G09AP00153: Economic Expert, International Upper Great Lakes Study

Basic Information

Title:	USGS Award No. G09AP00153: Economic Expert, International Upper Great Lakes Study
Project Number:	2009MI162S
Start Date:	8/7/2009
End Date:	3/31/2011
Funding Source:	Supplemental
Congressional District:	8
Research Category:	Social Sciences
Focus Category:	Management and Planning, None, None
Descriptors:	Upper Great Lakes, Economic Growth Scenarios, Climate Change, Water Regulation
Principal Investigators:	Jon Bartholic

Publications

There are no publications.

NO OTHER WORK IS BEING PERFORMED ON THIS PROJECT.

Title: Economic Expert, International Upper Great Lakes Study

Project Number: 2009MI162S (extended to FY2009)

Start: 08/07/2009(actual)

End: 03/31/2011(actual)

Funding Source: USGS ("104S")

Congressional District: eighth

Research Category: Social Sciences

Focus Categories: Management and Planning

Descriptors: Upper Great Lakes, Economic Growth Scenarios, Climate Change, Water Regulation

Primary PI: John Hoehn, Professor, Agricultural, Food, and Resource Economics, Michigan State University, 301A Agriculture Hall, East Lansing, MI 48824-1039, PH: 517.353.6735, hoehn@msu.edu

Project Class: Research

Introduction

The plan of work calls for the development of six of economic growth scenarios for the upper Great Lakes region over the next 20 to 40 years. The scenarios develop possible trajectories for economic growth in population and gross regional product. As these scenarios are develop, the research will examine how regional economic growth may influence the way society may choose to regulate water levels in the future through adaptive management.

General Statement

Problem/Demand

The researcher has reviewed the economic and scientific literature to assess current and projected trends and has reviewed the interests and vulnerabilities represented in the work of the technical working groups (TWGs). The researcher is in the process of finalizing the six growth scenarios and writing a final report.

Methodology

The research reviews the literature regard economic growth prospects for the upper Great Lakes in the next 30 to 40 years and summarizes the best economic and scientific analysis in the form of six economic growth scenarios.

Problem and Research Objectives

Six growth scenarios are developed that are consistent with the specifications described in the project plan of work. The first three scenarios are:

1. The current economy going forward 30 to 40 years with no change in population, gross regional product, and other economic factors
2. The current economy going forward 30 to 40 years and growth consistent with current trends.
3. A high growth scenario going forward 30 to 40 years.

The first three scenarios are developed assuming no climate change. The second set of three scenarios are developed incorporated climate change. Climate change considerations are incorporated from the research and summaries of the U.S. Global Change Research Program.

NO OTHER WORK IS BEING PERFORMED ON THIS PROJECT.

Principle Findings and Significance

The researcher is finalizing the six growth scenarios and writing the final report. The summary and review of literature revealed different prospects for sub-regions with Canada and the United States. The Canadian upper Great Lakes sub-region is the southwestern section of Ontario. Statistics Canada anticipates higher growth in the working population in this sub-region than analysts expect for the U.S. upper Great Lakes sub-region. Since the working population is linked directly with the growth potential of a region, the Canadian sub-region can expect higher rates of economic growth than can the U.S. sub-region of the upper Great Lakes.

Table 1 displays the different levels of growth expected by U.S. and Canadian sub-region for each of the three scenarios with no climate change. In the high scenario, population in the U.S. sub-region grows by 32% by 2050 and in the Canadian sub-region it grows by 52%. The disparity between sub-regions also show up in the gross regional products (GRPs). Under the high scenario, GRP in the U.S. sub-region more than doubles, but GRP in the Canadian sub-region more than triples by 2050. In the U.S. region, growth in the economy paces growth in the working age population so the number of jobs per capita remains constant under the high growth scenario. In the Canadian sub-region, jobs per capita grows by 32%.

**Table 1. Total and Percent Growth by Scenario, 2010 to 2050,
Upper Great Lakes Region**

Three Scenarios, No Climate Change	Population	GRP	Jobs	Jobs per Capita	Personal Income per Job
	(Thousands or %)	(\$Millions or)	(Thousands or)	(Number or)	(\$)
United States Sub-region					
No Change	10,542	413,005	6,084	0.58	56,759
Low Scenario	7%	97%	13%	6%	54%
High Scenario	32%	114%	32%	0%	62%
Canadian Sub-region					
No Change	12,610	553,016	6,985	0.55	--
Low Scenario	46%	141%	55%	9%	55%
High Scenario	52%	219%	84%	32%	92%

Publications

Not at this time.

USGS Award No. G10AC0034 Continued Technical Support of MI Water Withdrawal Assessment Process & Development of an Internet-Based Water-Use Database

Basic Information

Title:	USGS Award No. G10AC0034 Continued Technical Support of MI Water Withdrawal Assessment Process & Development of an Internet-Based Water-Use Database
Project Number:	2010MI183S
Start Date:	5/28/2010
End Date:	6/27/2011
Funding Source:	Supplemental
Congressional District:	
Research Category:	Social Sciences
Focus Category:	Water Use, Management and Planning, Groundwater
Descriptors:	Conjunctive Use
Principal Investigators:	Jon Bartholic, Jeremiah A Asher

Publications

1. Reeves, H.W., D.A. Hamilton, P.W. Seelbach, and A.J. Asher. 2009. Ground-Water-Withdrawal Component of the Michigan Water-Withdrawal Screening Tool: U.S. Geological Survey Scientific Investigations Report 2009-5003 (36 pages).
2. Reeves, H.W., D.A. Hamilton, P.W. Seelbach, and A.J. Asher. 2009. Ground-Water-Withdrawal Component of the Michigan Water-Withdrawal Screening Tool: U.S. Geological Survey Scientific Investigations Report 2009-5003 (36 pages).

Title: USGS Award No. G10AC0034 Continued Technical Support of MI Water Withdrawal Assessment Process & Development of an Internet-Based Water-Use Database

Project Number: 2010MI183S (extended to FY2011)

Start: 5/28/2010(actual)

End: 6/27/2011 (actual)

Funding Source: USGS ("104S")

Congressional District: eighth

Research Category: Social Sciences

Focus Categories: Water Use, Groundwater, Water Supply

Descriptors: Conjunctive Use

Primary PI: Dr. Jon F. Bartholic, Director, Institute of Water Research, MSU, 517.353.9785, bartholi@msu.edu; Jeremiah Asher, Program Manager, Institute of Water Research, MSU, 517.432.5586, asherjer@msu.edu

Project Class: Research

Introduction

Since the early 1900's, the U.S. Geological Survey (USGS) has published over 50 regional or county-scale studies of groundwater resources in Michigan, including those in bedrock and glacial aquifers. Furthermore, USGS has considerable expertise and experience in Michigan and nationally in the area of quantifying ground-water/surface-water interactions, a scientific issue central to development of the water-withdrawal assessment tool. The USGS Cooperative Streamgaging Network provides the basis for computation of streamflow statistics that are a key component of the prototype tool developed in 2006-07. USGS scientists were members of the Technical Advisory Subcommittee of the Ground Water Conservation Advisory Council that developed the water-withdrawal assessment process and screening tool. The USGS also recently completed, in a cooperative effort with MDEQ and Michigan State University (MSU), a statewide groundwater inventory and map in response to Public Act 148 of 2003. This inventory and map has key linkages to the water-withdrawal assessment tool.

On July 9, 2008, Michigan Public Act 185 of 2008 became law. This law requires the Michigan Department of Environmental Quality (MDEQ) to implement a water-withdrawal assessment process including an on-line water-withdrawal screening tool. A prototype water withdrawal assessment process and screening tool was developed in 2006-07 by the Michigan Ground Water Conservation Advisory Council in consultation with the Departments of Environmental Quality, Natural Resources (MDNR) and Agriculture, and a Technical Advisory Committee appointed by the Council.

General Statement

In January, 2012 the DEQ water use reporting interface was completed and transferred to the Michigan Department of Technology, Management, and Budget. The Department of Agriculture and Rural Development's water use reporting interface is almost complete and will be transferred and available for use in fall of 2012. The Water Withdrawal Assessment Tool is currently being upgraded to include a new mapping interface and enhanced database capabilities for the State of Michigan.



Problem and Research Objectives

Provide technical scientific support to the Departments of Environmental Quality and Natural Resources in the implementation of the water-withdrawal assessment process and screening tool that meets all of the requirements of Michigan Public Act 185 of 2008. Conduct research to improve the hydrologic framework used to underpin the assessment process and screening tool.

Methodology

A description of the approach to completing the project objective, including a workplan, milestones, review schedule, and interim products will be mutually agreed upon among USGS, MDEQ, and the Institute for Water Research at Michigan State University (IWR). All of the work on this project will require substantial collaboration and communication among these parties. All major decisions regarding the product and approach will be agreed upon by these parties. Key dates for the implementation of the water-withdrawal screening tool include: working version of the on-line screening tool, October 1, 2008; water-use accounting and tool assessment, February 1, 2009; and final full implementation of the on-line screening tool, July, 9, 2009.

Currently, the parties have agreed upon the following steps. The major USGS roles will be related to 1, 2, 4, 7, 8, and 9. IWR will be the lead for tasks 5 and 6, and it will have major roles in 7, 8, and 9. Note that MDNR will be the lead for task 3.

1. Update input data required by index-flow estimation procedures to eliminate errors encountered in the prototype version.
2. Update index flows for gaged and ungaged basins according to period of record specified in the legislation.
3. Update valley segment classification of stream reaches for the state.
4. Aggregate index flow to valley-segment catchment scale and add data necessary for estimation of streamflow depletion by a pumping well.
5. Update on-line screening tool based on legislation.
6. Link this process with the Water Use Data Base.
7. Provide a testing period for the Water Withdrawal Assessment Tool.
8. Provide technical scientific support for implementation of on-line screening tool.
9. Provide technical scientific support for future enhancements of the on-line screening tool and water-withdrawal assessment process.

Principle Findings and Significance

The water-withdrawal assessment tool will provide critical planning and regulatory information needed by multiple parties in the State of Michigan to make sound decisions regarding water withdrawals. This tool should have broad transferability to other parts of the nation with similar hydrologic characteristics.

Products

The final product will be an on-line water-withdrawal screening tool. MDEQ and MDNR also will establish the overall water-withdrawal assessment process. Upon project completion, no later than May 15, 2009, the product will be delivered to MDEQ for approval before the July 9, 2009 final implementation date.



USGS, IWR, MDNR, and MDEQ will agree upon a schedule of progress reviews, presentations, and demonstrations throughout the course of development of the final product and upon the agencies or organizations to be present at these reviews and presentations. Reviews and presentations will be regarded as interim products that show progress toward completion of the project and which constitute a basis for billing and ongoing funding.

The USGS may publish peer-reviewed USGS reports that document parts of the assessment tool, in consultation with MDEQ; however, due to time constraints they will not necessarily be completed by July 9, 2009.



USGS Award No. G10AP00153 The Great Lakes Tributary Modeling Program 516(e): Purdue University and Michigan State University

Basic Information

Title:	USGS Award No. G10AP00153 The Great Lakes Tributary Modeling Program 516(e): Purdue University and Michigan State University
Project Number:	2010MI184S
Start Date:	9/7/2010
End Date:	8/31/2011
Funding Source:	Supplemental
Congressional District:	8
Research Category:	Climate and Hydrologic Processes
Focus Category:	Sediments, Models, Management and Planning
Descriptors:	Fox River Basin of eastern Wisconsin, the Saginaw River Basin of eastern Michigan, the Maumee River Basin of northwestern Ohio, and the Genesee River Basin of western New York
Principal Investigators:	Jon Bartholic

Publications

There are no publications.

Title: The Great Lakes Tributary Modeling Program 516(e)

Project Number: 2010MI184S

Start: 09/07/10(actual)

End: 08/31/12 (actual)

Funding Source: USGS (“104S”)

Congressional District: eighth

Research Category: Climate and Hydrologic Processes

Focus Categories: Sediments, Models, Management and Planning

Descriptors: Fox River Basin of eastern Wisconsin, the Saginaw River Basin of eastern Michigan, the Maumee River Basin of northwestern Ohio, and the Genessee River Basin of western New York

Primary PI: Dr. Jon F. Bartholic, Director, Institute of Water Research, MSU,
bartholi@msu.edu

Project Class: Research

Introduction

Over the reporting period, IWR continued to support the sedimentation reduction efforts of the U.S. Army Corps of Engineers (USACE). Specifically, IWR built finer resolution sediment risk models for priority watersheds than had been previously available and developed dynamic web-based sediment risk modeling capabilities.

As part of prior USACE collaborations, IWR built erosion and sedimentation risk models for the entire Great Lakes Basin using the High Impact Targeting (HIT) approach. IWR made these models readily accessible for analysis and download through the HIT web mapping interface (www.iwr.msu.edu/hit2). However, to cover such a large geographic area IWR automated much of the HIT modeling process, which required broad assumptions among modeling parameters. In the current reporting period IWR developed more refined HIT models for the following priority Great Lakes Basin watersheds identified by USACE: the Fox River Basin of eastern Wisconsin, the Saginaw River Basin of eastern Michigan, the Maumee River Basin of northwestern Ohio, and the Genessee River Basin of western New York. The refinement of these HIT models included the utilization of county-level SSURGO soil surveys (1:24,000 scale) in place of state-wide STATSGO surveys (1:250,000 scale), 10-meter resolution digital elevation models in place of 30-meter models, multiple years of crop-specific location data in the USDA Cropland Data Layer in place of single year generic land cover data from the National Land Cover Dataset, and an enhanced calculation of the length-slope parameter for the Revised Universal Soil Loss Equation. These new HIT models will provide more reliable estimates of sediment loading and more precise identification of high-risk sediment loading locations in some of the Great Lakes Basins most sensitive watersheds.

To extend the analysis capabilities of the web-based HIT mapping interface, IWR developed functionality to allow for dynamic land cover change and BMP simulation. This functionality will be incorporated in a piloted mapping interface linking other water quality tools, such as Purdue University’s Long-term Hydrologic Impact Assessment (L-THIA), for the priority watersheds mentioned above. An experimental mapping interface is available for Fox River

Basin at

<http://www.arcgis.com/home/webmap/viewer.html?webmap=2e402d88cf2c4c4b8d54f4436f196fc0>. This interface is accessible on both PC and mobile devices such Apple's iPad. A watershed delineation geoprocessing service was also developed for the integration into the final system. Further Non Point Source modeling capability based on this watershed delineation function is also being developed. Once these capabilities have been integrated, users will be able to digitize polygons on a map, specify land-cover changes or a limited list of agricultural BMPs, and evaluate changes in erosion and sediment loading resulting from those changes, all on-line. IWR is currently testing this new functionality, and plans on making it available on-line for the priority watersheds by the end of 2012.

Final Report:
Sediment Modeling for the Manitowoc and Twin Rivers Watersheds
(Wisconsin)
July 2010 – Jun 2011

Prepared by:
The Institute of Water Research – Michigan State University
Manly Miles Building, Suite 101A
1405 South Harrison Road
East Lansing, MI 48823

Submitted to:
U.S. Army Corps of Engineers, Detroit District
477 Michigan Avenue,
Detroit, MI 48226-2523

Summary:

The goal of this project was to utilize the High Impact Targeting (HIT) approach to develop sediment-risk models for the Manitowoc and Twin River watersheds of eastern Wisconsin (Figure 1). These models are intended to guide and prioritize the installation of agricultural best management practices, so as to maximize their effectiveness at reducing sediment loading to streams. The Institute of Water Research (IWR) at Michigan State University utilized and enhanced previous HIT models it had developed for other Great Lakes tributaries to deliver GIS data and web-based tool instruction to two key decision making groups in the study area. The Manitowoc and Calumet County Land and Water Conservation departments are the primary organizations for promoting and managing sediment-related best management practices in the study area. Therefore, IWR generated HIT models specifically for those organizations, and met in person with their staff to deliver the results, gather feedback, and conduct initial field evaluations of the models. IWR incorporated the staff feedback into refinements of the web-based HIT decision support tool.

Background:

From the HIT website (www.iwr.msu.edu/hit2):

HIT combines an erosion model (RUSLE - Revised Universal Soil Loss Equation¹) and a sediment delivery model (SEDMOD - Spatially Explicit Delivery Model²) to calculate annual erosion and sediment loading to streams for areas of the Great Lakes Basin. This combination yields two outputs: field-scale maps identifying areas at risk for erosion and sediment loading, and tonnage estimates for erosion and sediment loading at watershed scales. This on-line tool allows users to interact with these data spatially, and evaluate the potential impacts of best management practices (BMPs) on selected watersheds.

The Corps of Engineers and IWR have utilized this approach in a number of projects over the past six years, from coarse Great Lakes basin-wide studies³ to finer individual watershed studies.

HIT is a relatively simple model when compared to more sophisticated sediment load estimators, such as SWAT. However, HIT's calculation on a cell-by-cell basis give it superior spatial resolution, allowing for targeting within individual fields. Furthermore, its simplicity has allowed IWR to successfully automate HIT and generate data for large geographic areas (e.g. the entire Great Lakes Basin).

Study Area:

¹ Renard, K.; Foster, G.; Weesies, G.; McCool, D.; Yoder, D. *Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE)*. USDA, Agriculture Handbook Number 703, 1996.

² Fraser, R. *SEDMOD: A GIS-based Delivery Model for Diffuse Source Pollutants* (doctoral dissertation. Yale University. May 1999

³ Ouyang, D.; Bartholic, J.; Selegan, J. "Assessing Sediment Loading from Agricultural Croplands in the Great Lakes Basin." *The Journal of American Science*. Vol. 1, No. 2, 2005.

This project focused on the Manitowoc and Twin River basins of eastern Wisconsin (Figure 1), which drain into Lake Michigan. These basins are comprised of five 10-digit sub-watersheds: East Twin River-Frontal Lake Michigan (0403010101), West Twin River (0403010102), North Branch Manitowoc River (0403010103), South Branch Manitowoc River (0403010104), Manitowoc River-Frontal Lake Michigan (0403010106). These sub-watersheds have a total area of roughly 48,600 acres, of which seventy percent are classified as agriculture⁴. The study area is dominated by C (52%) and B (24%) hydrologic soil groups⁵, and is has gently sloping topography with a total relief of 170 meters⁶. IWR has generally produced HIT models one 8-digit watershed at a time. Therefore, for this project, data was generated for the entire Manitowoc-Sheboygan watershed (HUC – 04030101), which included the study area (Figure 2).

Task 1 – Model development:

HIT models for the study area existed before the start of this project. They were generated as part of an on-going Corps effort to provide sediment modeling data for the entire Great Lakes Basin. However, these particular models were part of an automated modeling routine, which required relatively coarse inputs and broad, general assumptions. For example, 30-meter resolution USGS Digital Elevation Models (DEMs), 1:100,000 – scale STATSGO soil surveys and National Hydrography Dataset (NHD) streams, averages from state-wide tillage use, and simplified length-slope calculations were employed to produce these initial models. For this project, IWR generated new HIT models that utilized 10-meter DEMs, 1:24,000 scale SSURGO soil surveys and streams, averages from county-level tillage use, and a more robust length slope calculation. Furthermore, IWR employed remotely sensed crop data from the USDA's Cropland Data Layer (CDL) to improve the spatial and temporal resolution of land cover in the model; this had not been done in any previous HIT modeling project.

The Model Inputs

1. Watershed boundaries – NRCS Watershed Boundary Dataset. Used to define the study area.
2. Topography – 1/3 arc-second DEM (10-meter) from the National Elevation Dataset. Used to simulate surface water flow and calculate slope-lengths for RUSLE.
3. Soils – SSURGO soil surveys for each county in the study area. Used to extract RUSLE K-factors and SEDMOD's percentage of clay.
4. Land Cover – 2006 National Land Cover Dataset (NLCD), a 30-meter resolution remotely sensed land cover product. Used to calculate SEDMOD's surface roughness component, and part of RUSLE's C-factor.
5. Crop types – Five years of CDL (2006-2010). Used with NLCD to estimate RUSLE C-factor.
6. Tillage practice – Three years of tillage survey data (2000, 2002, and 2004) from the Purdue University's Conservation Technology Information Center. The surveys report the number

⁴ 2006 National Land Cover Dataset

⁵ SSURGO Soil Surveys

⁶ USGS National Elevation Dataset

- of acres of certain crops, under the various tillage practices, for each county in the survey area. Used with NLCD and CDL to estimate RUSLE's C-factor.
- 7. Streams – NHD high resolution dataset. Used to simulate the stream network.
- 8. Climate – Oregon State University's PRISM dataset. Used to represent RUSLE's R-factor (rainfall intensity).
- 9. Common Land Unit (CLU) – Farm Services Agency. Used to aggregate sediment loading estimates at field levels, allowing for systematic field prioritization.

The Process

1. The necessary model inputs were gathered and clipped to the study area boundary (Figure 2)
2. SSURGO soil surveys for each county were processed in USDA's Soil Data Viewer extension for ArcMap. K-factor and Percentage Clay attributes were extracted and converted to raster datasets.
3. NLCD land cover classes were re-classified to appropriate Manning's roughness coefficients and RUSLE C-factor values gathered from literature.
4. For agricultural land cover cells, C-factors were calculated through a combination of CDL and tillage survey data (Figure 3). For each cell, five years of corresponding CDL cells were observed. Knowing the crop rotation from year to year in each cell, appropriate C-factors were selected from Wisconsin NRCS's RUSLE Technical Guide. These C-factors were then weighted by the extent of conservation tillage for each crop to yield a C-factor for each CDL year (except the first year, since the previous year crop was unknown). The C-factors were then averaged to yield a final C-factor for the particular cell.
5. The NHD high-resolution dataset was extracted and converted to a raster dataset, then used to "burn" streams into the study area DEM (enforces the stream network's location into the simulated surface flow).
6. The RUSLE LS factor was calculated by implementing a process detailed by Robert Hickey⁷.
7. PRISM R-factor data was clipped to the study area boundaries.
8. SEDMOD was run yielding a sediment delivery ratio for each cell.
9. RUSLE was calculated for each cell by multiplying R, C, K, and LS factors.
10. Sediment was calculated for each cell by multiplying the RUSLE and SEDMOD outputs.
11. Estimates of sediment loading at sub-watershed and CLU scales were calculated by aggregating values from corresponding sediment cells.

The Outputs (on supplementary DVD)

1. *sediment* – GIS raster of sediment values (*del_ratio* * *erosion*)
2. *sediment.lyr* – ArcGIS layer file, providing symbolization of *sediment* for cartographic display.
3. *erosion* – GIS raster of erosion values (RUSLE calculation)
4. *erosion.lyr* – ArcGIS layer file, providing symbolization of *erosion* for cartographic display.
5. *del_ratio* – GIS raster of delivery ratio values (SEDMOD output)
6. *huc10* - 10-digit watershed boundaries of the study area, with estimates of total sediment loading, total erosion, sediment loading per acre, and erosion per acre for each sub-watershed.

⁷ Van Remortel, R., M. Hamilton, and R. Hickey, 2001. "Estimating the LS factor for RUSLE through iterative slope length processing of digital elevation data". *Cartography*, v. 30, no. 1, pp. 27-35.

7. *huc12* – 12-digit watershed boundaries of the study area, with estimates of total sediment loading, total erosion, sediment loading per acre, and erosion per acre for each sub-watershed.
8. *clu* – Common Land Unit boundaries of the study area, with estimates of total sediment loading, total erosion, sediment loading per acre, and erosion per acre for each CLU.

Analysis

HIT's estimate of total annual sediment loading⁸ in the Manitowoc – Sheboygan 8-digit watershed was roughly 321,000 tons (SEDMOD * RUSLE) out of 1,938,000 tons of soil erosion (RUSLE), for a delivery rate of about 17% of eroded soil. For the project study area, total sediment loading was roughly 138,000 tons out of 830,000 tons of soil erosion, for a delivery rate of about 17%.

Figure 4 illustrates total sediment loading and corresponding ranking for each 10-digit watershed in the Manitowoc – Sheboygan watershed. While the project study area of the Twin Rivers and Manitowoc basins (Figure 4 rankings 2,3,5,6,12) does contain some large contributing sub-watersheds, the results indicate that the Sheboygan River basin (Figure 4 ranking 1) warrants additional attention. The map of sediment loadings and rankings by 12-digit watersheds (Figure 5) also draws attention to the Sheboygan River basin; however, it is worth noting that the single largest contributing 12-digit watershed (Neshota River – 040301010203) is in this project's study area.

Figure 6 illustrates how HIT data was aggregated at the CLU level to further enhance conservation staff's ability to target individual fields. As Figure 5 could be utilized to prioritize 12-digit sub-watersheds and subsequently identify Neshota River as an area of concern, Figure 6 could be utilized to identify particular fields of concern within the Neshota River watershed, and Figure 7 could be used to identify sediment-risk areas within prioritized fields.

Task 2 – Tech transfer and updated HIT interface:

In June 2011 IWR staff visited the offices of the Calumet and Manitowoc Land and Water Conservation Departments on consecutive days. Prior to the meeting, IWR took the data generated in Task 1, organized it, documented it with FGDC-compliant metadata, and burned it onto DVDs with accompanying PDF map books (see Figures 8 - 11 for an excerpt) and read-me files for each Land and Water Conservation Department. IWR provided presentations on the HIT modeling process and demonstrations of the on-line tool, and then accompanied conservation staff for field evaluations of HIT sediment risk maps.

Discussions on the tool's utility and how IWR could improve the interface followed the presentation. Conservation Department staff were generally satisfied with HIT's current interface, and their only main recommendation for improvement was more detailed help documentation. Some individuals reported getting lost in a task, and that they would have benefited from on-line instructions. To address this need, IWR updated HIT's help page to include links to detailed tutorials and video demonstrations

⁸ It is important to note that HIT's estimates are of delivery from the land to the stream network. HIT does not route sediment to the basin outlet, nor does it account for bank erosion.

produced by the Annis Water Resource Institute at Grand Valley State University (Figure 12). While additional instruction on how to use the on-line HIT tool will be helpful to future users of HIT, most of the conservation staff rely on desktop GIS for their day to day operations. Therefore, for them, it is equally if not more important to provide detailed metadata and documentation for the offline HIT data stored on the disc to the conservation departments. IWR included this information on those discs.

With each conservation department, IWR and staff visited a number of fields to evaluate the HIT model outputs. HIT generally targeted fields conducive to erosion and sediment loading, but clear evidence of erosion (gullies, residue run-off, etc.) was often not present due to the fact that most exposed soil was already covered by growing crops, and because of the recent lack of strong, erosive storms. Regardless, conservation staff were generally pleased with HIT's targeting of fields, though a more thorough evaluation is needed to make a definitive conclusion of its effectiveness in the study area.

Figures 13 – 18 show HIT model outputs and photographs of visited sites. Figures 13 – 15 are from sites in Calumet County. In Figure 13, photograph C is of the dark red area (relatively high HIT estimates of sediment loading) circled in yellow in photograph B, viewed from north looking south from the road. The conditions of the field are conducive to sediment loading (agricultural land, moderate relief, proximity to stream), but there was little evidence of recent erosion. Again, this could be attributed to the lack of recent storms and the presence of ground cover. Figure 14 reflects a similar situation. The view of the red area is from northeast looking southeast from the road. There is significant relief draining into the drainage ditch running along the road; however the field appears to be fallow and under cover, mitigating any erosion and sediment loading. In Figure 15, view of the dark red area is from the south looking north from the road. The ditch near the road did contain some crop residue, indicating runoff from the field.

Figures 16 – 18 are from sites in Manitowoc County. The ground-photographs of the Manitowoc county sites were taken in rainy weather, making some of the features in those photos harder to see. In Figure 16, the dark red area at site 16- 1 is from the south looking north from the road. As with some of the Calumet county sites, conditions at site 16-1 are conducive to erosion and sediment loading, but there was no clear evidence visible on the day of the visit. The red area at site 16-2 is from the south looking north from the road. There is clear evidence of residue run-off in the southeast corner of the field. In Figure 17, the view of the pink area at site 17-1 is from the east looking west from the road. Conditions were conducive to erosion and sediment loading, but no clear evidence is visible in the roadside photograph. However, the aerial photo in 17-A clearly indicates the presence of channelized flow through the field, and corresponds to linear nature of the HIT high risk areas in 17-B. In Figure 18, the view of the red area at site 18-1 if from the south looking north from the road. Residue run-off is visible at the front of the picture. The dark red area at site 18-2 is from the southwest looking northwest from the road. HIT's mis-classification of this site was due to an error in the land cover input. NLCD classified this site as agriculture, when it should probably have been considered grassland.

Conclusion:

The data generated for this project should help the Calumet and Manitowoc County Land and Water Conservation Departments better target their sediment conservation practices. In particular, the Calumet director called the timing of the project's completion "ideal" since they were beginning to develop their state-mandated Land and Water Management Plan, which requires the development of sediment reduction goals and the identification of critical areas. The conservation staff of Manitowoc County has already developed its plan, but HIT provides them with a means to evaluate their selection of critical areas, and strategize for future revisions of the plan.

Future work in this study area could include a more thorough field evaluation of the HIT results, in order to build confidence in the model and encourage its use. Additionally, based on initial analyses of sub-watersheds within the Manitowoc-Sheboygan basin, further attention should be paid to the Sheboygan River basin, and partnerships with local decision makers who might benefit from HIT's data should be established.

Figures:

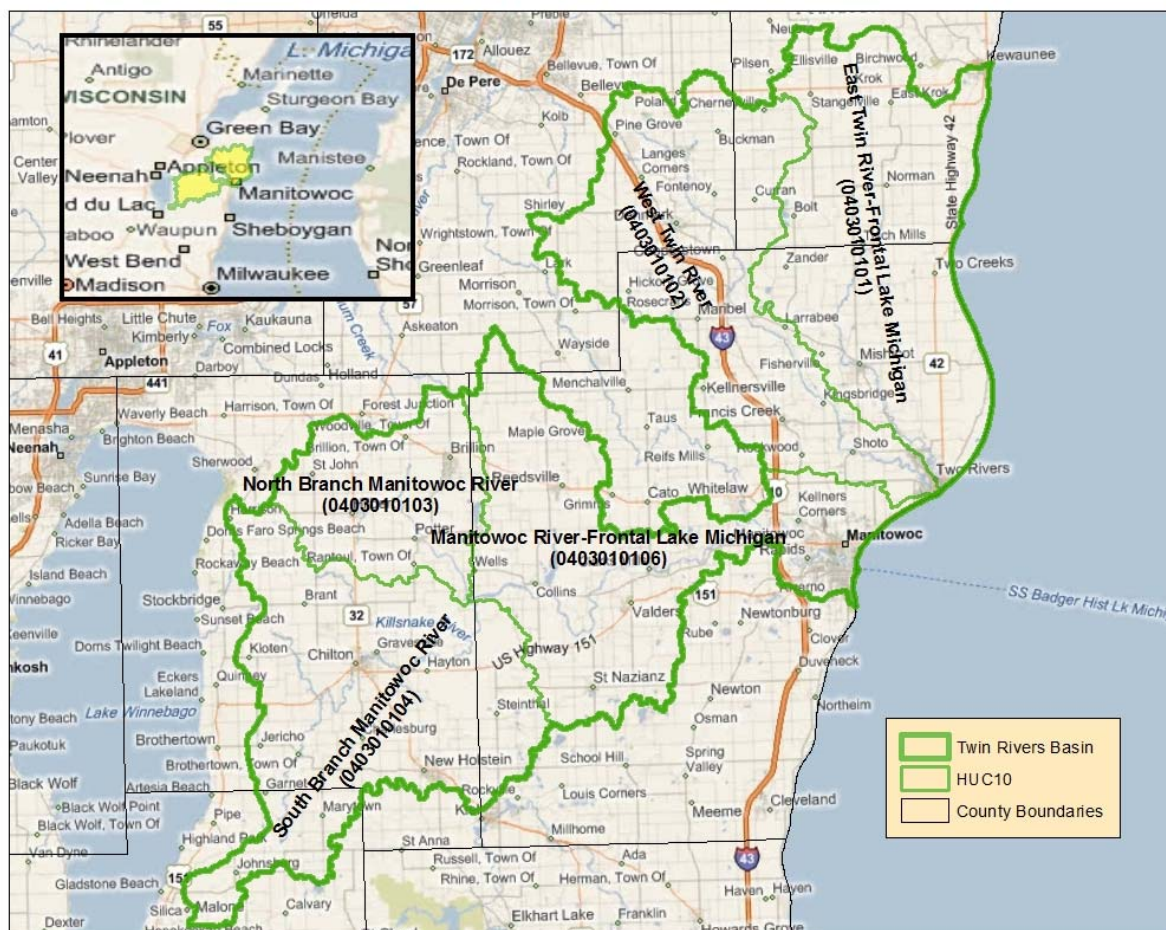


Figure 1: The Twin Rivers Basin study area.

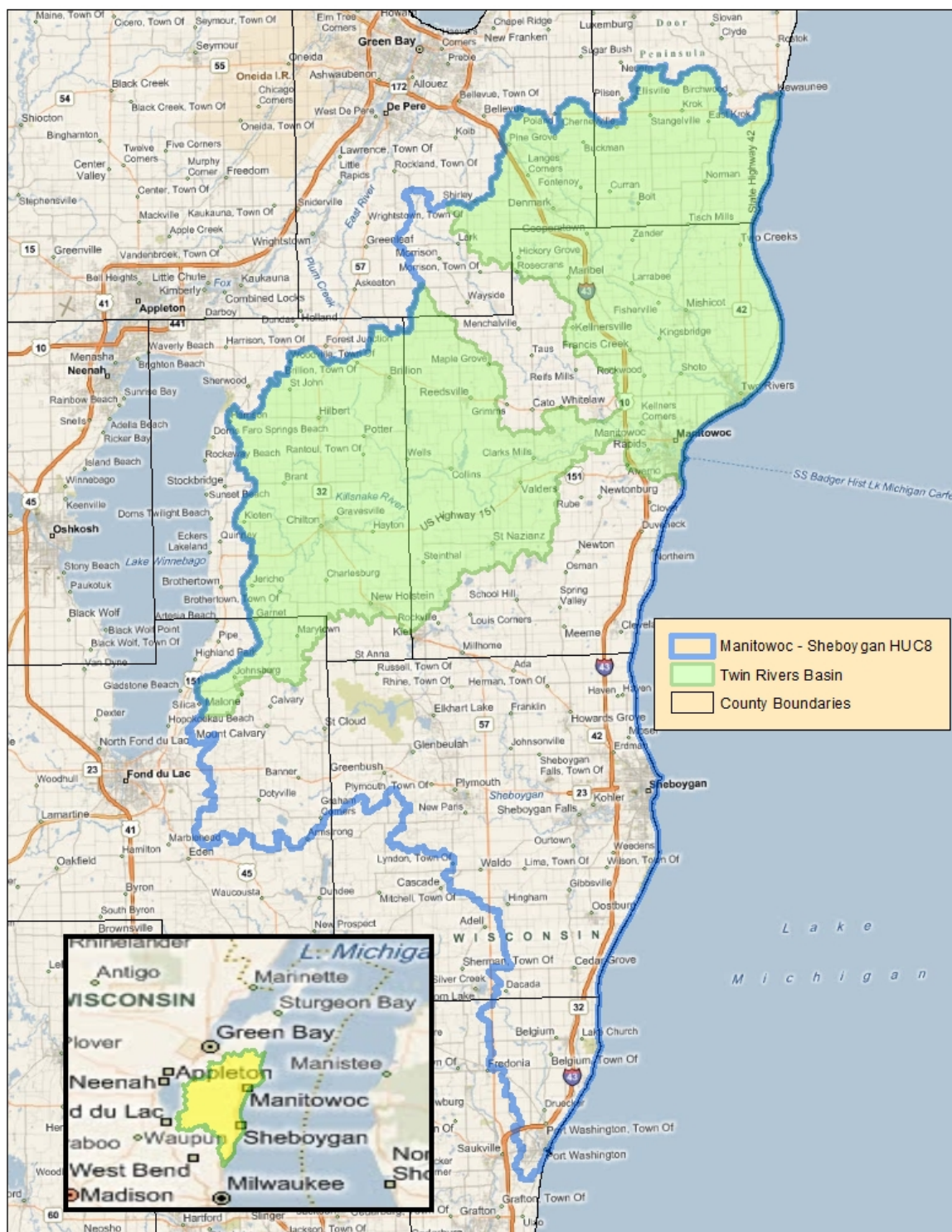


Figure 2: The Manitowoc - Sheboygan 8-digit watershed.

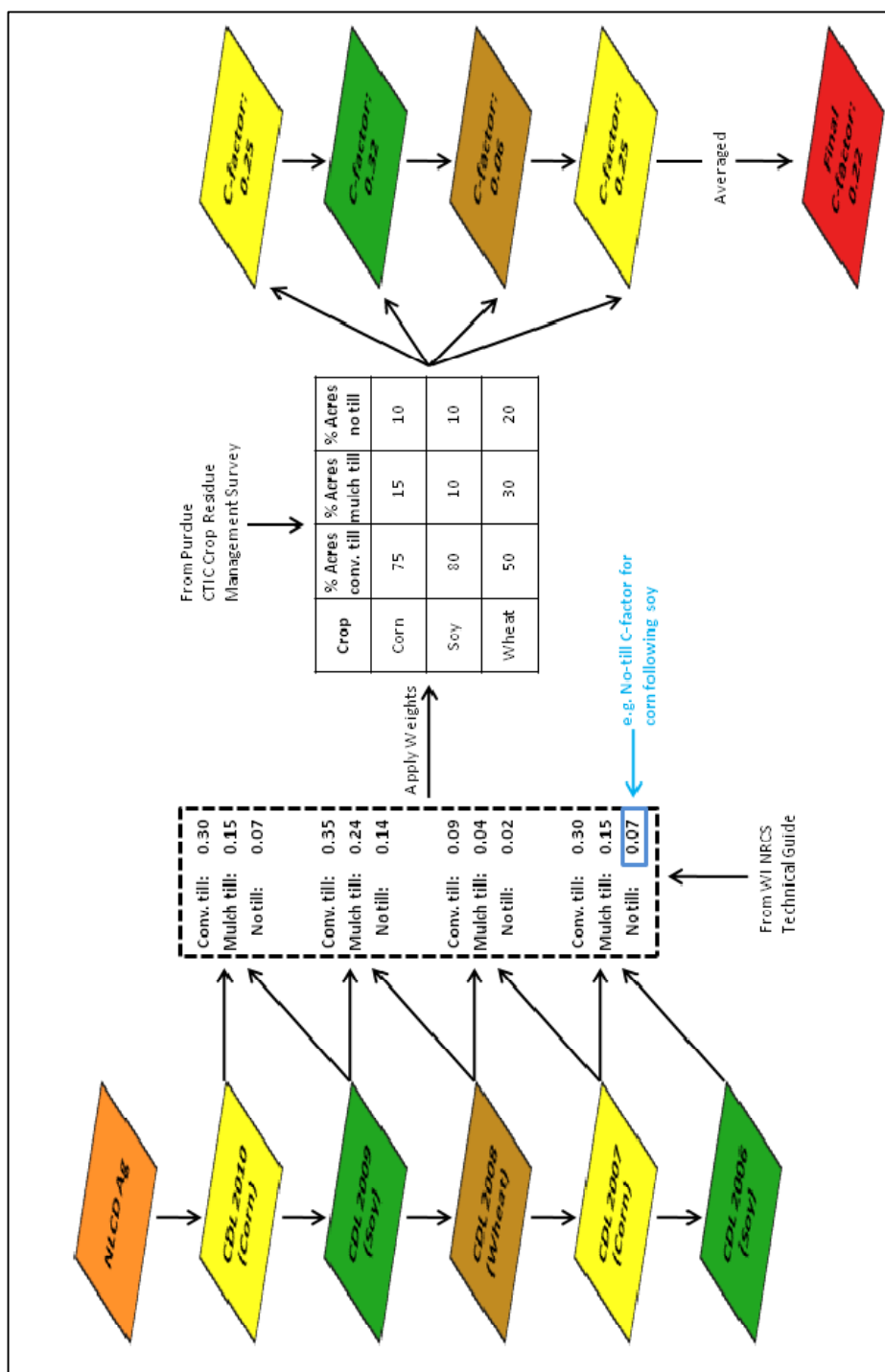


Figure 3: Calculating RUSLE C-factor for each raster cell.

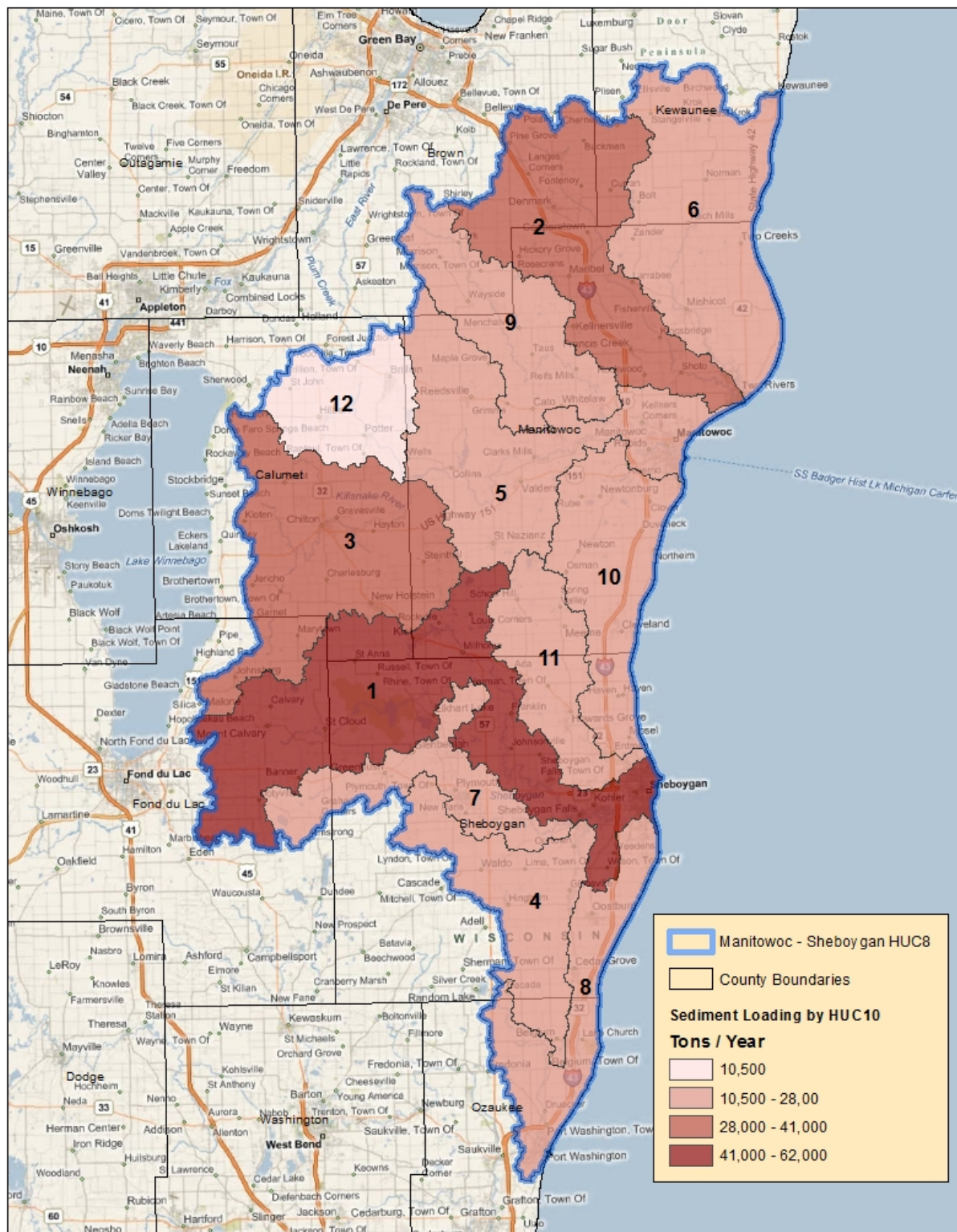


Figure 4: Total sediment loading by HUC10. The number in each watershed represents that HUC's ranking in terms of annual sediment loading, with 1 corresponding to the watershed with the most loading. See Table 1.

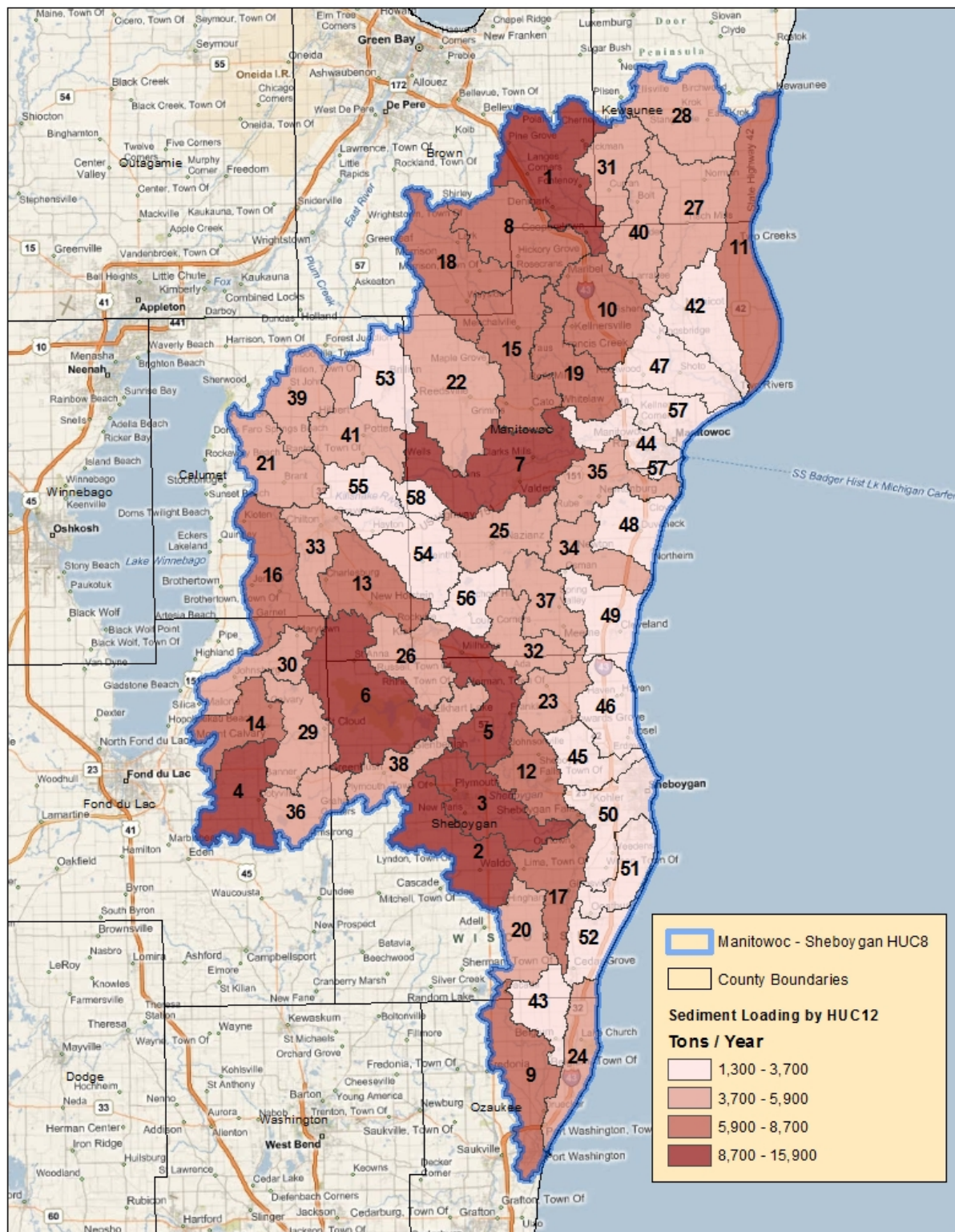


Figure 5: Total sediment loading by HUC10. The number in each watershed represents that HUC's ranking in terms of annual sediment loading, with 1 corresponding to the watershed with the most loading. See Table 2.

Sediment Loading Rank	HUC	Name	Total Annual Sediment Loading (tons)
1	0403010111	Sheboygan River-Frontal Lake Michigan	62,091
2	0403010102	West Twin River	40,955
3	0403010104	South Branch Manitowoc River	34,750
4	0403010110	Onion River	28,092
5	0403010106	Manitowoc River-Frontal Lake Michigan	26,052
6	0403010101	East Twin River-Frontal Lake Michigan	25,481
7	0403010109	Mullet River	20,046
8	0403010112	Black River and Sauk and Sucker Creeks-Frontal Lake Michigan	19,490
9	0403010105	Branch River	19,097
10	0403010107	Sevenmile and Silver Creeks-Frontal Lake Michigan	17,590
11	0403010108	Pigeon Creek	17,217
12	0403010103	North Branch Manitowoc River	10,532
Total			321,393

Table 1: Sediment loading by HUC10.

Sediment Loading Rank	HUC	Name	Total Annual Sediment Loading (tons)
1	040301010203	Neshota River	15,875
2	040301011001	Upper Onion River	12,373
3	040301010903	Lower Mullet River	12,163
4	040301011102	Headwaters Sheboygan River	11,908
5	040301011107	Otter Creek-Sheboygan River	10,885
6	040301011104	Sheboygan Lake-Sheboygan River	10,689
7	040301010603	Cato Falls-Manitowoc River	10,259
8	040301010202	Devils River	8,722
9	040301011204	Sauk Creek	8,490
10	040301010204	Francis Creek-West Twin River	8,294
11	040301010101	Molash Creek-Frontal Lake Michigan	7,951
12	040301011108	City of Sheboygan Falls-Sheboygan River	7,241
13	040301010403	Pine Creek	6,970
14	040301011101	Community of Mt. Calvary	6,607
15	040301010502	Middle Branch River	6,524
16	040301010402	Stony Brook-South Branch Manitowoc River	6,416
17	040301011004	Lower Onion River	6,352
18	040301010501	Upper Branch River	6,313
19	040301010503	Lower Branch River	6,260

20	040301011003	Middle Onion River	5,858
21	040301010406	Headwaters Killsnake River	5,694
22	040301010601	Village of Reedsville-Mud Creek	5,451
23	040301010803	Middle Pigeon Creek	5,419
24	040301011203	Sucker Creek-Frontal Lake Michigan	5,135
25	040301010602	Village of St. Nazianz-Mud Creek	5,122
26	040301011106	Kiel Marsh State Wildlife Area-Sheboygan River	5,074
27	040301010104	Tisch Mills Creek-East Twin River	5,056
28	040301010102	Krok Creek-East Twin River	4,972
29	040301011103	Feldner's Creek-Sheboygan River	4,906
30	040301010401	Headwaters South Branch Manitowoc River	4,774
31	040301010201	Black Creek	4,698
32	040301010802	Upper Pigeon Creek	4,431
33	040301010404	City of Chilton-South Branch Manitowoc River	4,167
34	040301010703	Point Creek	4,035
35	040301010701	Silver Creek	4,018
36	040301010901	Upper Mullet River	3,972
37	040301010801	Meeme River	3,970
38	040301010902	Middle Mullet River	3,911
39	040301010301	Headwaters North Branch Manitowoc River	3,906
40	040301010103	Jambo Creek	3,859
41	040301010303	North Branch Manitowoc River	3,829
42	040301010105	East Twin River	3,643
43	040301011002	City of Belgium	3,509
44	040301010605	Manitowoc River	3,437
45	040301010804	Lower Pigeon Creek	3,397
46	040301010705	Sevenmile Creek-Frontal Lake Michigan	3,393
47	040301010205	West Twin River	3,366
48	040301010702	Pine Creek-Frontal Lake Michigan	3,132
49	040301010704	Centerville Creek-Frontal Lake Michigan	3,012
50	040301011109	Sheboygan River-Frontal Lake Michigan	2,992
51	040301011201	Black River	2,952
52	040301011202	Barr Creek-Frontal Lake Michigan	2,913
53	040301010302	Spring Creek	2,797
54	040301010405	Cedar Creek	2,763
55	040301010407	Killsnake River	2,678
56	040301011105	Cedar Lake	1,789
57	040301010604	Little Manitowoc River-Frontal Lake Michigan	1,783
58	040301010408	South Branch Manitowoc River	1,288

Table 2: Sediment loading by HUC12.



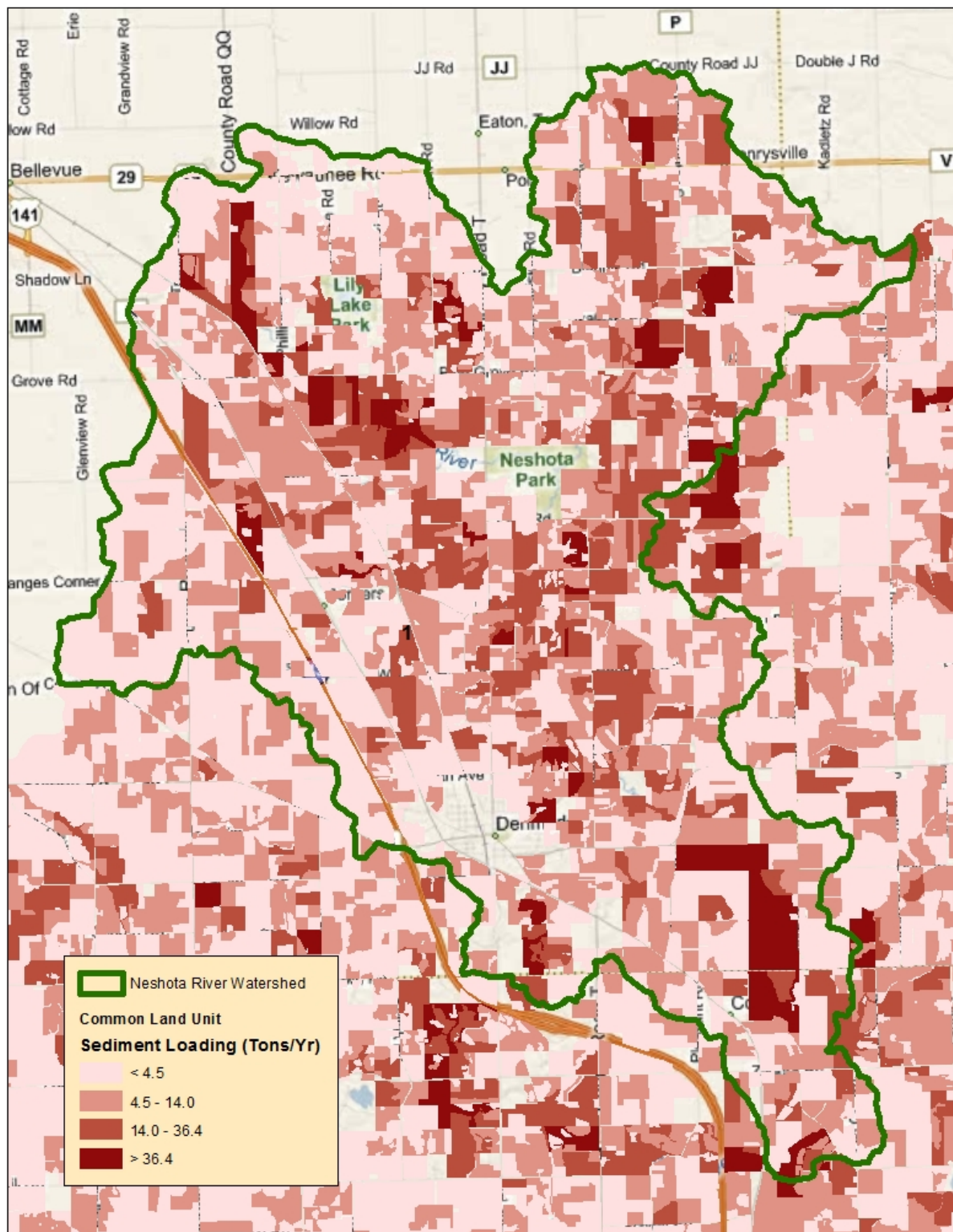


Figure 6: Sediment loading totals by Common Land Unit (CLU).

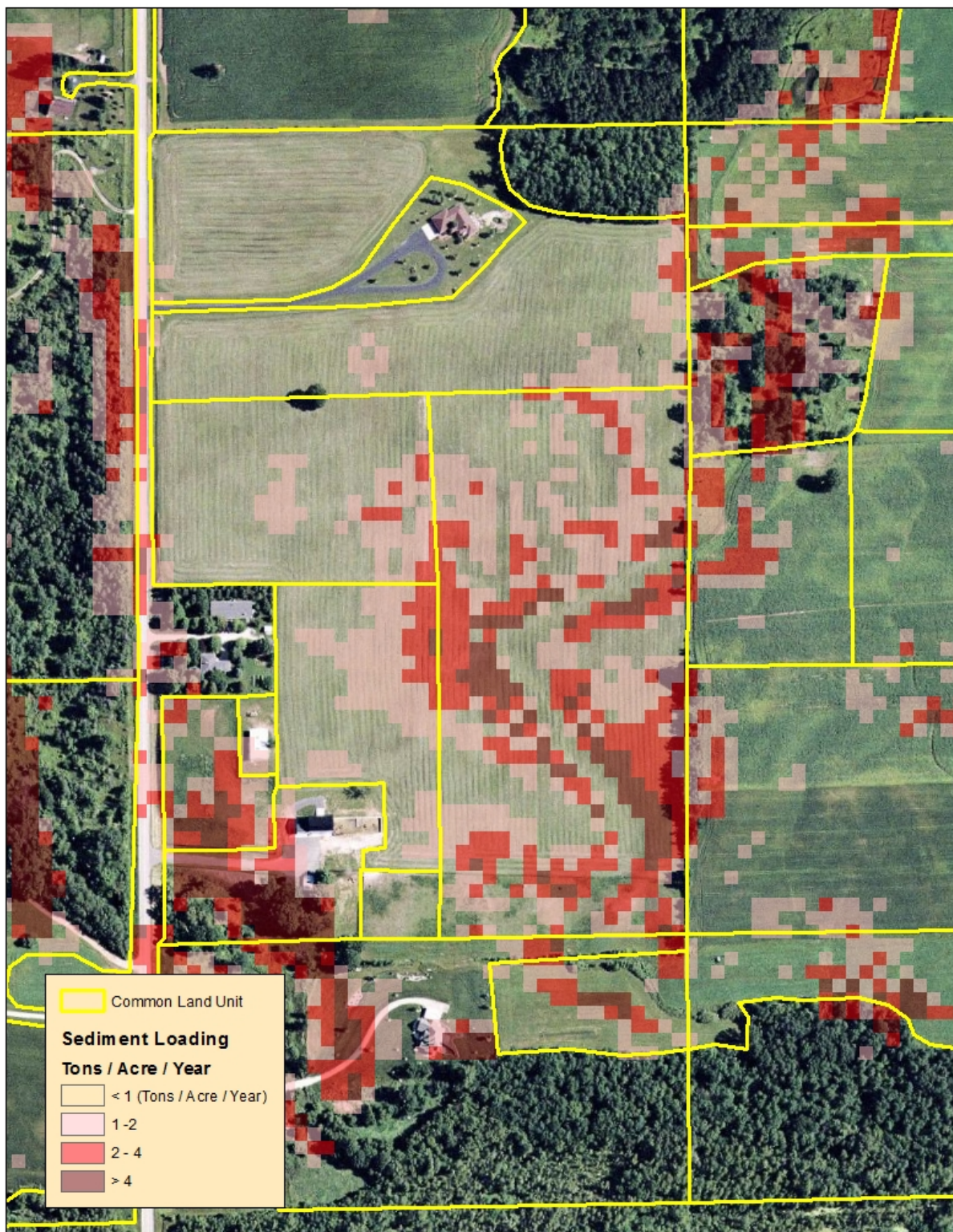


Figure 7: Sediment loading by 100m2 area.

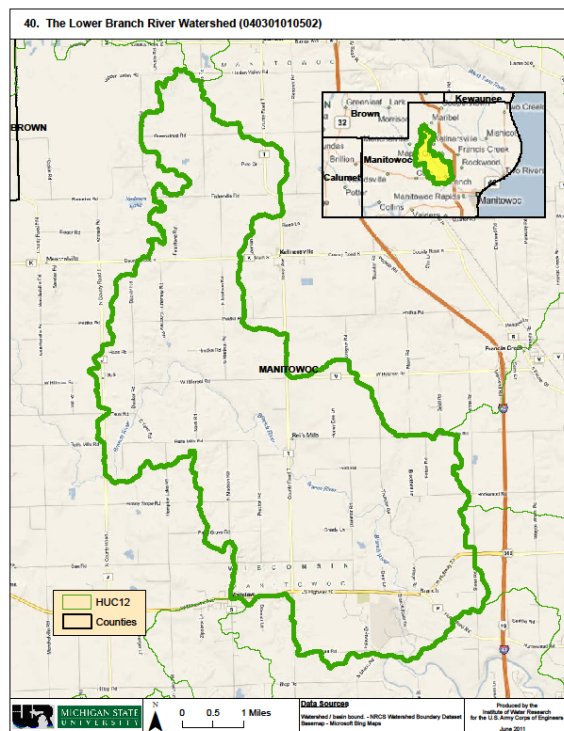


Figure 8: Mapbook excerpt - Basemap of a HUC12

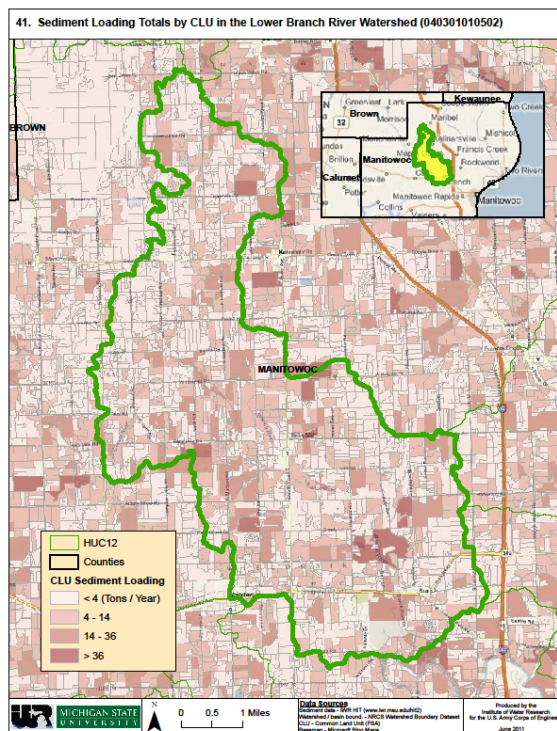


Figure 9: Mapbook excerpt - Sediment loading totals by CLU for a HUC12.

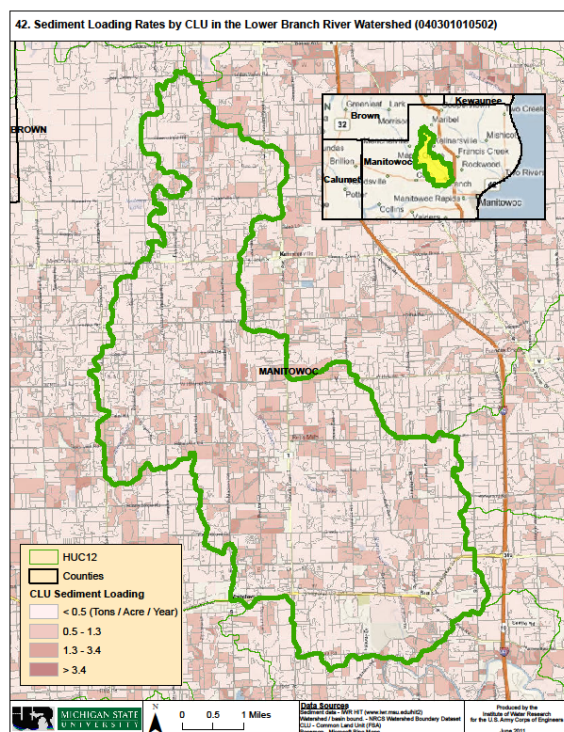


Figure 10: Mapbook excerpt - Sediment loading rate by CLU for a HUC12.

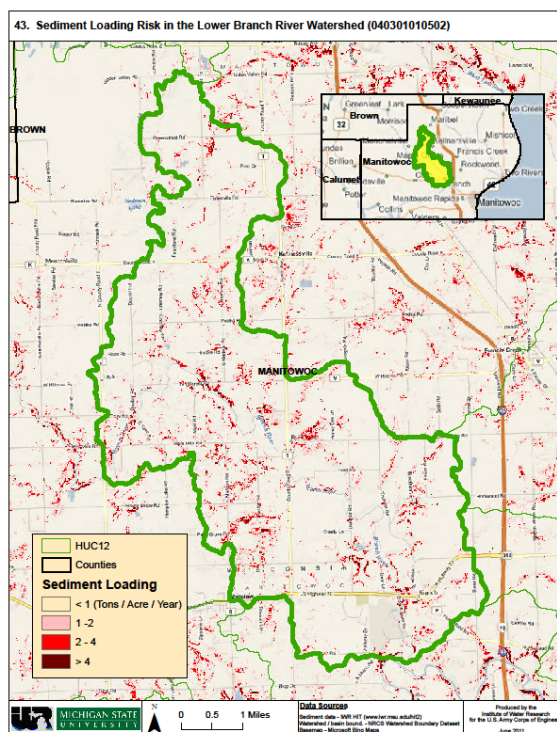


Figure 11: Mapbook excerpt - Sediment loading risk by cell for a HUC12.



Figure 12: Video help files for on-line HIT.

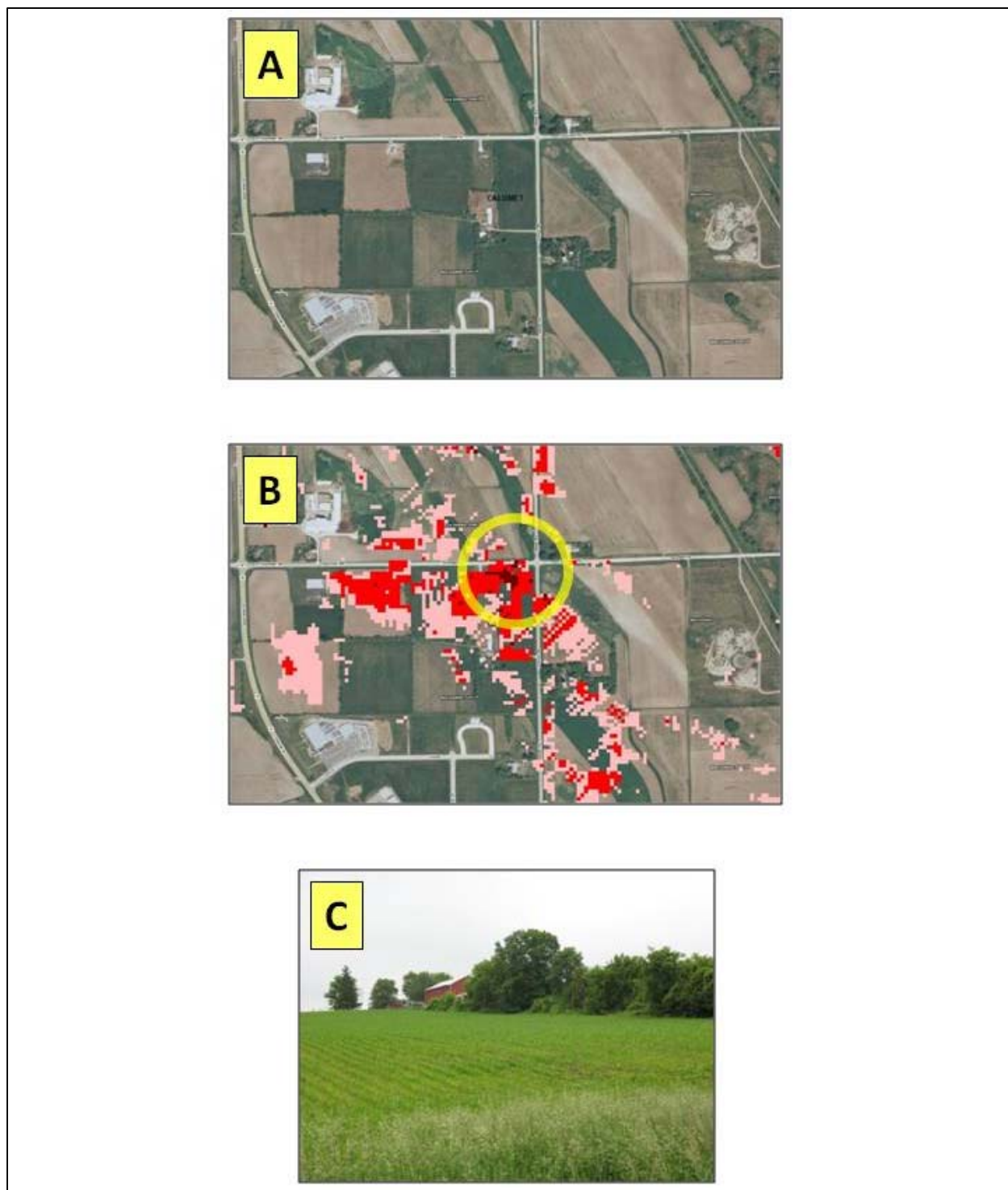


Figure 13: Calumet county HIT field evaluation.

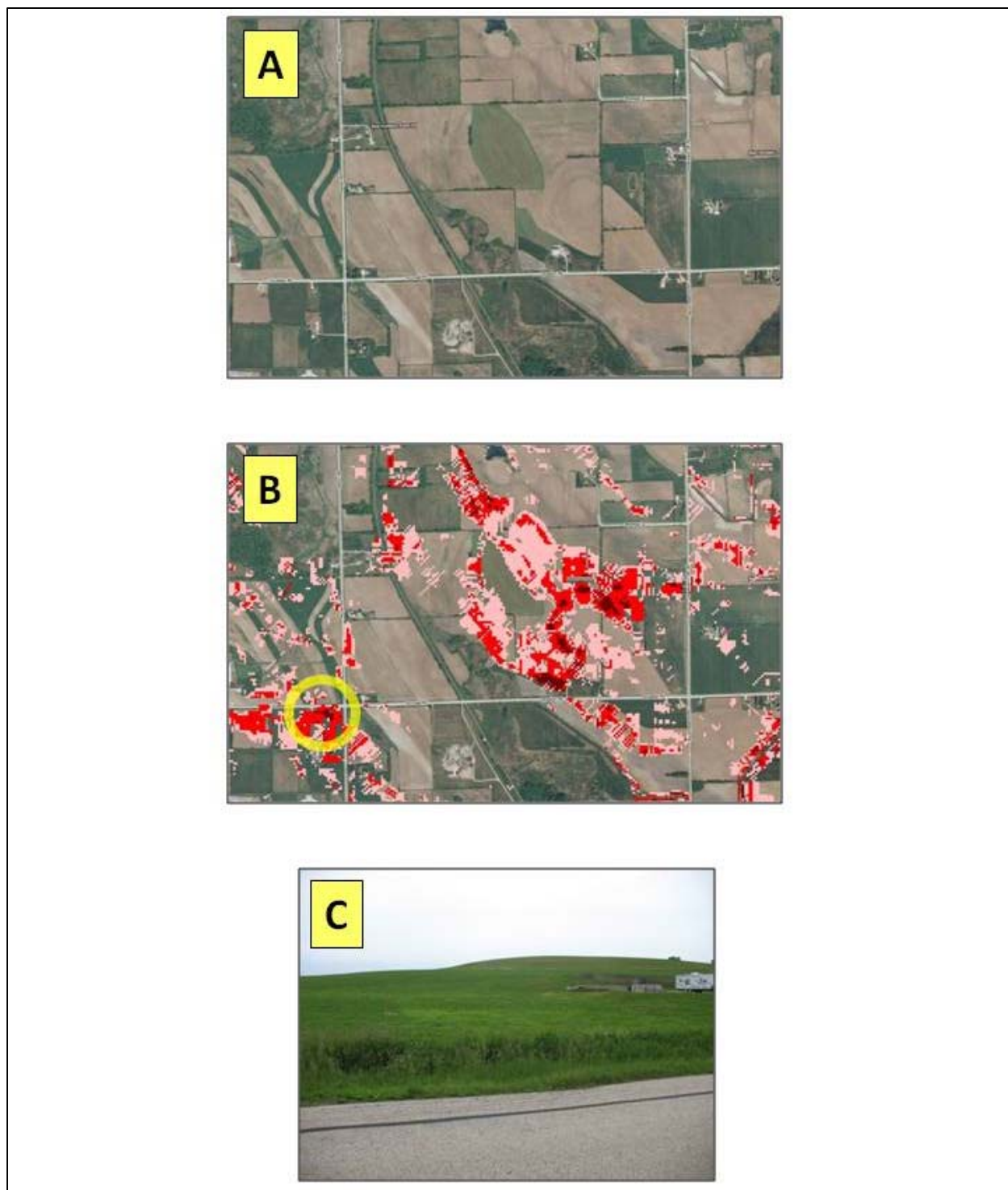


Figure 14: Calumet county HIT field evaluation.

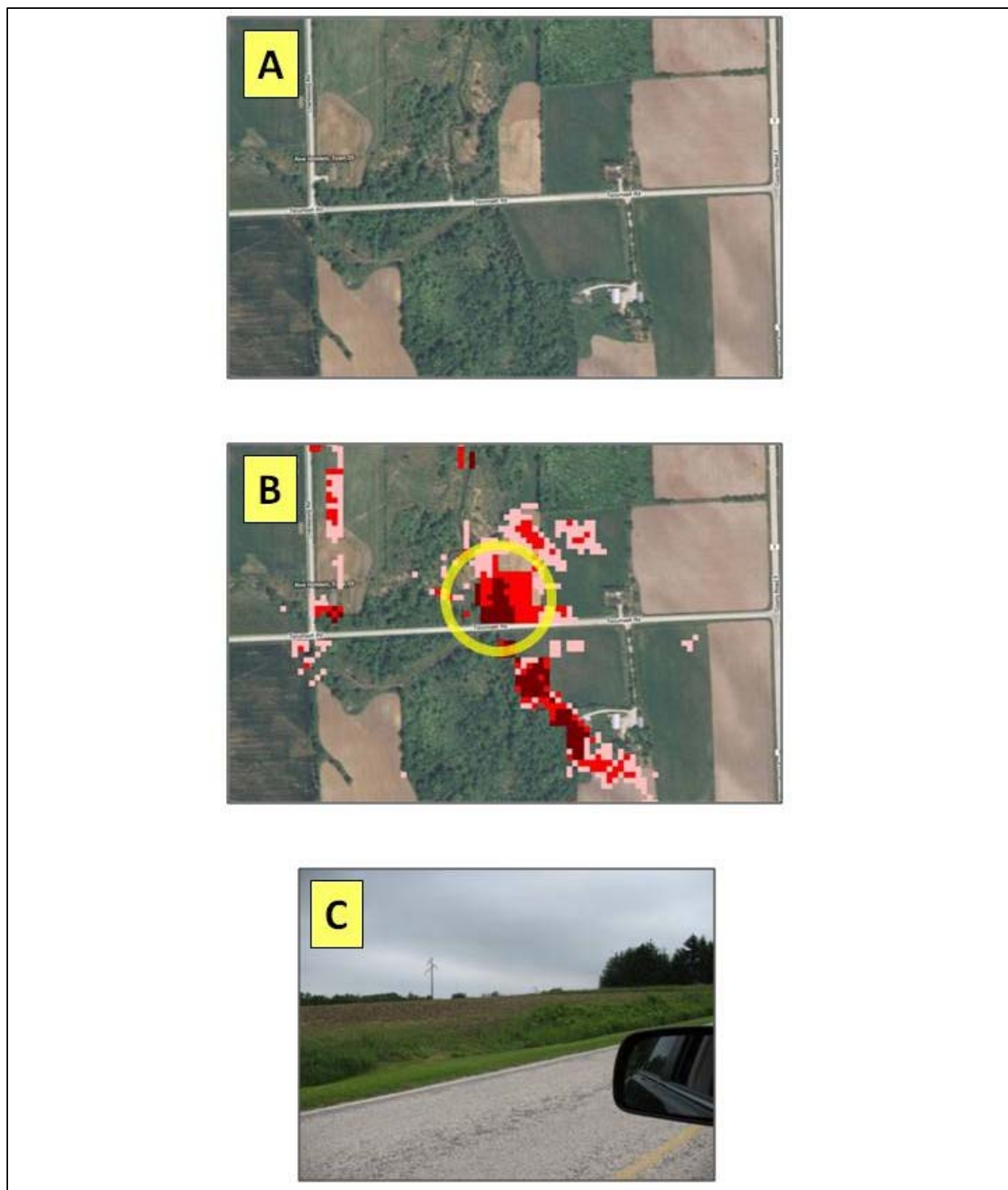


Figure 15: Calumet county HIT field evaluation.

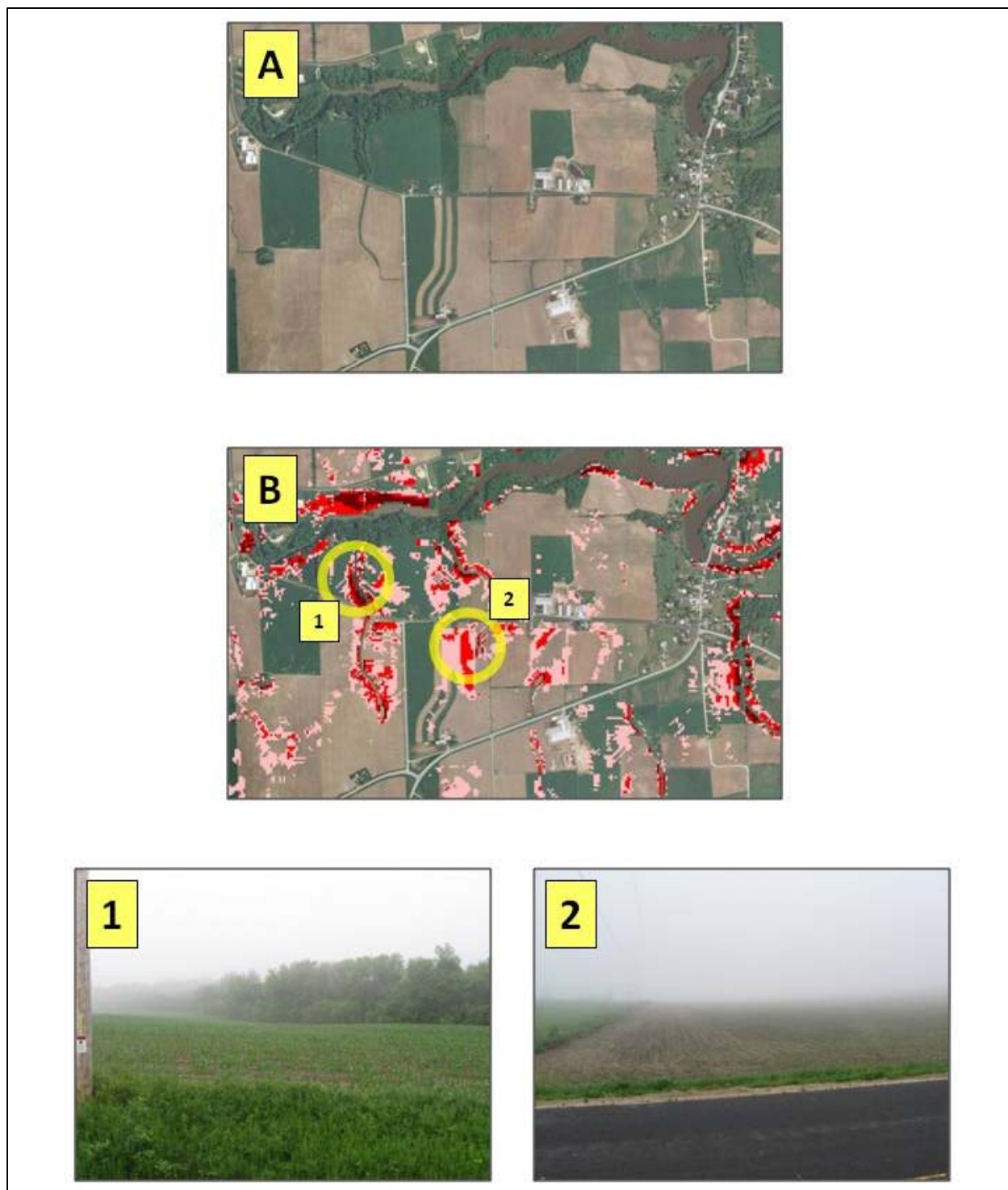


Figure 16: Manitowoc county HIT field evaluation.

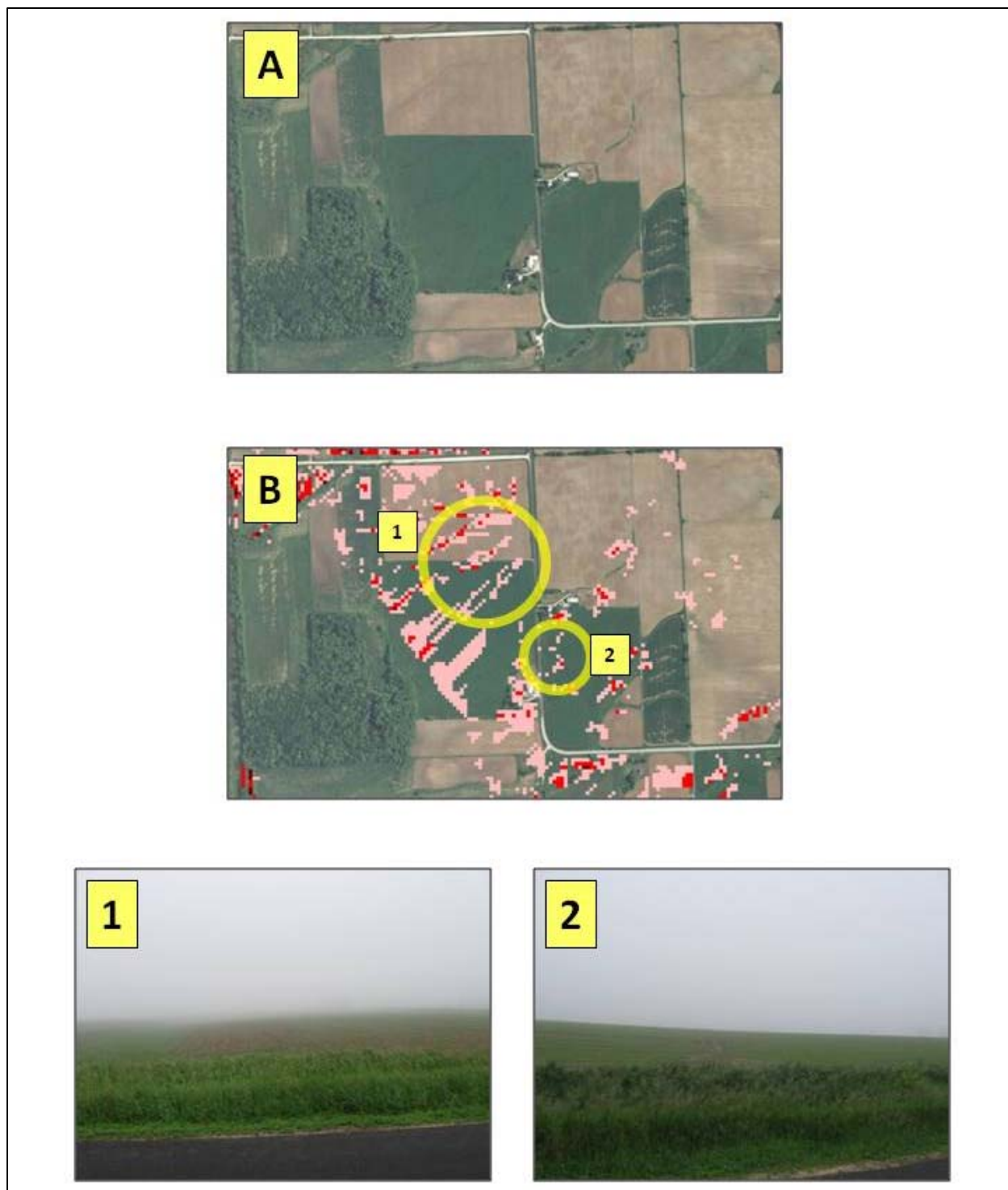


Figure 17: Manitowoc county HIT field evaluation.

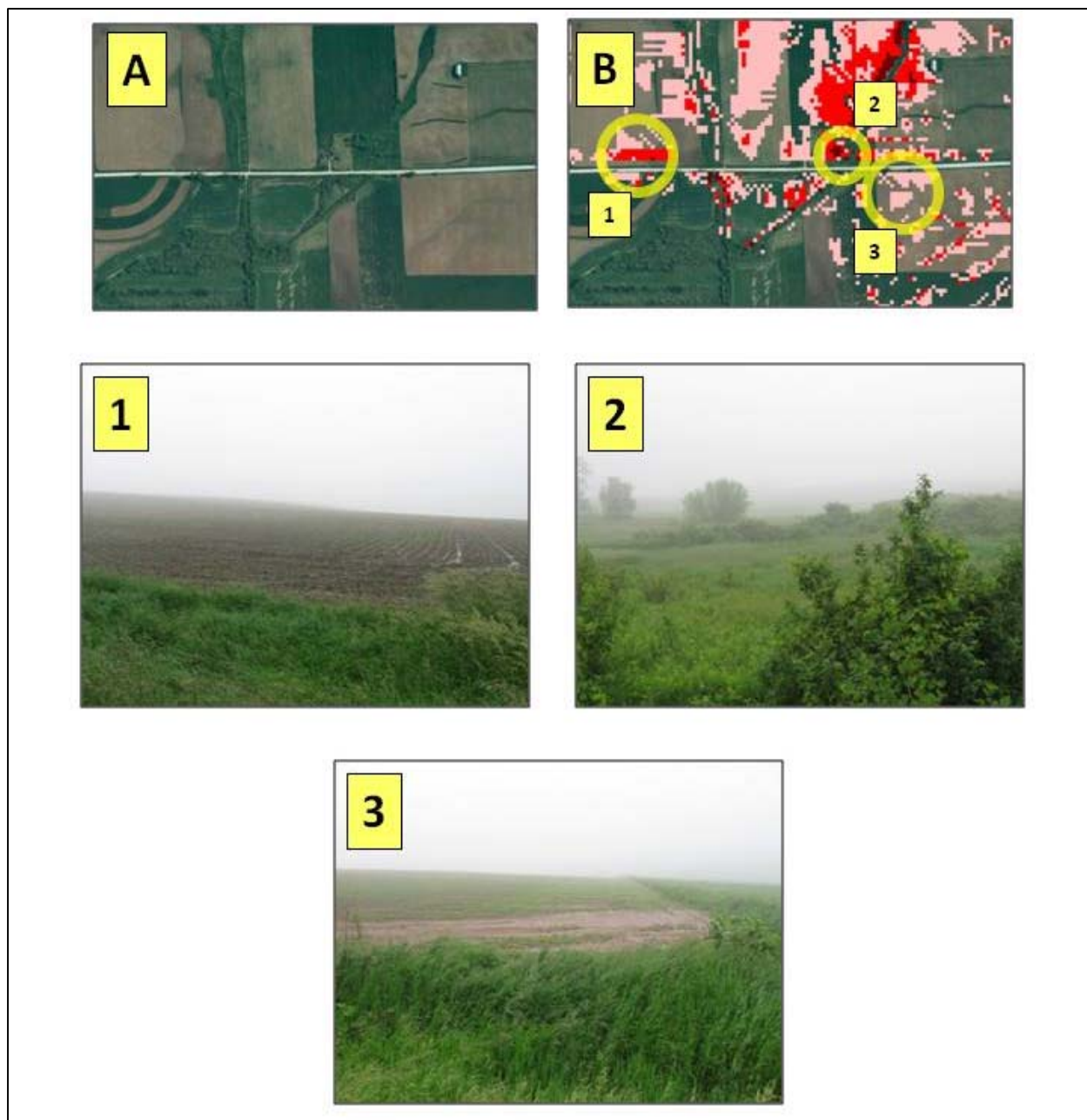


Figure 18: Manitowoc county HIT field evaluation.

Natural Resources Integrated Information System

Basic Information

Title:	Natural Resources Integrated Information System
Project Number:	2011MI185B
Start Date:	3/1/2011
End Date:	2/28/2012
Funding Source:	104B
Congressional District:	8
Research Category:	Water Quality
Focus Category:	Management and Planning, Water Quality, Water Use
Descriptors:	None
Principal Investigators:	Jon Bartholic

Publications

1. Bartholic, J., Y. Shi, K. Maredia, S. Seedang, J. MacDonagh-Dumler. 2010. Institute of Water Research and Institute of International Agriculture, Michigan State University, "Characteristics of an Action Plan for Addressing Emerging Issues in Water Management for Sustainable Agriculture in South Asia Region." Submitted to the Central Soil & Water Conservation Research & Training Institute Research Centre, India for inclusion in Proceedings from the Indo-US Workshop on Emerging Issues in Water Management for Sustainable Agriculture in South Asia Region, December 10-12, 2009, in Udhagamandalam, Tamil Nadu, India. In Press.
2. Bartholic, J., W. Northcott, S. Miller, A.J. Asher, S. Seedang, S. Gasteyer, and J. Andresen. 2010. Refining the Water Needs and Availability for Michigan's Agriculture from a Spatial and Temporal Perspective." Project GREEN identification number (GR08-087).
3. Bartholic, J., O'Neil, G., Shi, Y. 2009. A Web-Accessible Watershed-Based System Targets Land Areas at Highest Risk for Sediment Loss to Streams. On Line Proceedings 2009 at <http://www.benthos.org/Other-Publications/NABSTRACTS/2009/4406.aspx>, North American Benthological Society, Grand Rapids, MI.
4. Seedang, S., Fernald, A., Adams, R., Landers, D. 2008. Economic Analysis of Water Temperature Reduction Practices in a Large River Floodplain: an Exploratory Study of the Willamette River, Oregon, Wiley InterScience on line at www.interscience.wiley.com, 19 pages.
5. O'Neil, G., Y. Shi, J. Bartholic, R. Fanelli, B. Engel, J. Hunter. 2008. Swan Creek Watershed Project Final Report submitted to U.S. Army Corps of Engineers in fulfillment of funding requirements. 17 Pages.
6. Shi, Y., 2009. Midwest Spatial Decision Support System Partnership, Exchange Network Grant Program Semi-Annual Progress Report for Grant OS-83320901-0, submitted to Wisconsin DNR to Environmental Protection Agency. 21 pages.
7. Wolfson, L., Editor. R. Schaetzel, J. Darden, D. Brandt. 2008. Michigan Geography and Geology. Pearson Custom Publishing at <http://www.mypearsonstore.com/bookstore/product.asp?isbn=0536987165>.
8. Isely, E, P. Isely, S. Seedang, K. Mulder, A. Steinman, and K. Thompson. 2010. Addressing the Information Gaps Associated with Valuing Green Infrastructure in West Michigan: Integrated Valuation of Ecosystem Services Tool (INVEST). Journal of Great Lakes Research 36(3):448-457.
9. Seedang, S. and P. Norris. 2010. Water Use in Michigan. Technical paper. Michigan Agricultural Experimental Station (in press).

Natural Resources Integrated Information System

10. Adelaja, S. Y. Hailu, A. Tekle and S. Seedang. 2010. Evidence of Land Hoarding Behavior in US Agriculture. *Agricultural Finance Review* 70(3) 377-398.
11. Seedang, S., S. Batie, and M. Kaplowitz. 2010. Using Bio-Physical Information to Structure a Ground Water Conservation Credit Program (draft manuscript paper).
12. Seedang, S., P. Norris, and J. Bartholic. 2010. The Role of Water Conservation Technology, Economics, and Institutions for Reducing Water Use Conflicts, Michigan Case Study (Proceedings abstract). The American Water Resources Association Annual Conference, Seattle, WA, November 9-12, 2009.
13. Norris, P., S. Seedang, and M. Thompson. 2009. Water Use and Water Demand by Self-Supplied Residential Water Users in Michigan. Technical Paper No. 2008MI118B for USGS Natural Resources Integrated Information System; US Dept of Geological Services.
14. Reeves, H.W., D.A. Hamilton, P.W. Seelbach, and A.J. Asher. 2009. Ground-Water-Withdrawal Component of the Michigan Water-Withdrawal Screening Tool: U.S. Geological Survey Scientific Investigations Report 2009-5003 (36 pages).
15. O'Neil, G. 2010. Conservation Innovation Grant final report, Impact Targeting: applying conservation tools to the worst areas for maximum sediment/nutrient reductions. Submitted to Michigan Department of Agriculture.
16. O'Neil, G., 2009. Presented at ACOE Detroit District Managing and Understanding Sediments in Your Watershed meeting, Web-based tools for soil erosion assessment/management: HIT, DW, RUSLE, in Buffalo, NY, Dec. 8-9.
17. O'Neil, G., J. Bartholic, Y. Shi. 2010. High Impact Targeting Decision Support System for BMPs to Most Effectively Reduce NPS Pollution, presented at the 18th National Nonpoint Source Monitoring Workshop, Nov. 16-18 in Milwaukee, WI. In Press
18. O'Neil, G., L. Theller, Y. Shi, J. Bartholic, B. Engel. 2010. The Swan Creek Watershed Management System, presented by O'Neil at the TMDL 2010: Watershed Management to Improve Water Quality ASABE Conference, Nov. 14-17 in Baltimore, MD. In Press
19. Bartholic, J. 2010. Presented at Great Lakes Tributary Modeling Program 516(e) All Hands Meeting; Partner Updates: Web-based Model Development and Other Activities, in Ann Arbor, MI, June 22.
20. Asher, A.J. 2010. Networked Neighborhoods for Eco-Conservation (NEC) Online presented to the Holland Community Energy Advisory Group by Jeremiah Asher of MSU-Institute of Water Research's Web-based Mapping Project; October 7 at City Flats Hotel-Theater Room downtown Holland, MI.

Title: Natural Resources Integrated Information System

Project Number: 2011MI185B

Start: 03/01/11(actual)

End: 02/29/12 (actual)

Funding Source: USGS 104(B)

Congressional District: eighth

Research Category: Water Quality

Focus Categories: Management and Planning, Water Quality, Water Use

Descriptors: Management and Planning, Water Quality, Water Use

Primary PI: Jon F. Bartholic, Director, Institute of Water Research, Michigan State University, East Lansing, MI 48823, bartholi@msu.edu

Project Class: Research

Problem and Research Objectives

Nature and Importance to the Problem and Relevance to the Mission

Water is replacing oil as one of the single most important resources upon which policy and, in fact, human existence in many portions of the globe will depend. Political power, economics, and civilization's development will be critically impacted by our ability to sustainably manage and optimally utilize the planet's water resources. Because of the United States' relative advantage from a water resource standpoint, this country's role will be increasingly significant in food production and industrial production requiring significant quantities of water, and in developing sustainable approaches to maintain waters' ecological services. Specifically, the Great Lakes region will have tremendous opportunities to capitalize in numerous ways on the potential of its vast water resources. But water resources management always occurs in a social context involving multiple stakeholders. Stakeholders can have radically different perceptions of the problems and potential trade-offs associated with finding solutions because of dynamic social, economic, and political factors as well as biophysical complexities of water resources issues. This complex nature of water resource management and other related issues, such as global climate change and health care, is often referred to in the scientific community as "wicked." Research on wicked-type problems suggests that a comprehensive knowledge system sustained by a boundary organization is essential. Boundary organizations act as intermediaries between science and policy because they fulfill or possess (see Figure 1): 1) specialized roles within the organization for managing the boundary; 2) clear lines of responsibility and accountability to distinct social arenas on opposite sides of the boundary; and 3) a forum in which information can be co-created by research and interested parties. Since its very beginning and long history of existence, the Institute of Water Research (IWR) has been functioning as a boundary organization to tackle wicked water resources management issues. Through a history of extensive knowledge generation, engagement and facilitation, and working experience with local, state, and basin-wide organizations, IWR has a solid base of success to build upon in creating innovative knowledge systems for sustainable management of water resources.

Previous Work and Present Outlook

Three current IWR projects illustrate approaches to solving wicked problems. The first project involves a nearly six-year experience in the co-creation, facilitation, and support for the State of



Michigan's Water Withdrawal Assessment Process to meet the requirements of the Great Lakes Basin Water Resources Compact (Steinman, et al. 2010) The assessment process integrates surface and groundwater hydrology and fisheries resource models to predict potential adverse resource impacts from water withdrawals. The role of IWR was to provide key input to state legislators and convene a science advisory committee. Also, IWR was assigned the task of developing the legislatively-designated web-based tool that is currently being used to assess potential water withdrawals. The second example, in place for the last seven years encompasses work with non-point source pollution reduction with the support of numerous agencies including the U.S. Army Corps of Engineers, EPA, MDA, USDA_NRCS, MAES, MSUE, and several foundations including the Frey and the Grand Rapids Community Foundation. As part of this large effort, IWR developed a model to evaluate sediment contributions to the tributaries of the Great Lakes and its harbors. The model was used by IWR to identify and map the agricultural areas contributing the greatest sediment loadings. This enabled the Corps to begin targeting its sediment reduction efforts at a macro scale. More recently, IWR worked with MDA and USDA NRCS to refine this targeting approach at the local level in three Michigan watersheds. These watershed projects allowed IWR to complete development of a more refined High Impact Targeting (HIT) decision support system.

The HIT system is designed to aid federal, state, and local decision makers with prioritizing their sediment reduction efforts (O'Neil, Bartholic and Shi 2010; O'Neil, Theller, et.al. 2010). A third example involves IWR collaborating internationally with three Borlaug Fellows from India and the MSU Institute of International Agriculture (Bartholic, Shi, Maredia, et.al. 2010). The joint international effort included an Indo-U.S. Workshop on "Emerging Issues in Water Management for Sustainable Agriculture in South Asia Region" in Tamil Nadu, India. This event was jointly organized by the Central Soil & Water Conservation Research & Training Institute (Indian Council of Agricultural Research) and Michigan State University. MSU was represented by the Institute of International Agriculture and IWR. The workshop was attended by top level representatives from over ten major water management programs. As a result of this workshop, a South Asia Water Knowledge and Innovation Network was formed, and IWR will be a major player in the expansive new efforts initiated at this workshop.

Our vision is to create an institute that effectively links science and technology for the sustainable management of water resources. There is a great need for local, state, national and international water resources management decisions and policies to be based on thorough scientific research and multidisciplinary expertise. IWR works across multiple units within the University and with numerous external partners. As water resources issues become more complex, IWR will embrace and strive to enhance its service as a boundary organization by advancing the understanding of wicked problems related to water issues among academia, state partners, NGOs, citizens of Michigan, and the global community and through the research and development of new decision support systems that help address these complex problems.

Methodology

Research Methods/Experimental Procedures

The manner in which we have engaged in team efforts with the scientific community from across campus, the state and region has been effective and provides an approach upon which we can build. As previously mentioned, we have an evolving process which will help us to transform our



institute to more effectively address “wicked” problems. The advisory body will be critical in guiding the re-creation of our activities, which will lead to more holistic and effective approaches to addressing “wicked” problems. This transformation may be aided through support and input from various internal individuals and entities, including departments and units within CANR such as the proposed new Department of Natural Resources Ecology and Management, Department or focal area of Sustainable Studies and Biosystems Engineering. In addition, Dr. Hiram Fitzgerald, Director of University Outreach and Engagement, and colleagues, are refining a community-based systems approach for affecting change in social systems, which IWR may incorporate as a component of this new strategy. These various inputs will guide our initial activities. In addition to its staff members who have expertise in a broad array of water resources management topics, including database development and information systems, GIS, aquatic ecology and community-based water management programming, IWR has historically worked with many diverse faculty members representing a broad cross section of water resources expertise across MSU colleges. A listing of the faculty members and students who have recently worked with and received support from IWR on various water resources management projects was included in a recent report compiled for the Water Resources Partnership, a jointly funded agreement between the Michigan Department of Natural Resources and Environment (formerly the MDEQ) and MSU.

Our first achievement strategy is to build on and transform current IWR strengths, partnerships, and reputation. By working in a co-creative framework with individuals, policymakers and organizations to integrate the science and knowledge base, IWR is generating adaptive and dynamic systems for management of critical water resources that includes ecological, social and economic components.

- (1) Reorganize IWR to more effectively link knowledge with action, i.e., connecting knowledge generation and local applications by becoming an appropriately structured boundary organization. The structure depicted in Figure 1 shows that IWR will not only serve as a critical link between the research and knowledge generated by the scientific community (i.e., entities at the University) and the user community, but will also serve to facilitate the co-creation of knowledge (middle column, Figure 1) by working with the end users (right column) and the scientific community (left column).
- (2) Actively be involved in facilitating, leading, demonstrating and evaluating the co-creation process through numerous specific activities involving “wicked” problems. Water resources management with consideration for economic development is a complex or “wicked” problem because it often demands organizations/stakeholders at all levels to come together and find acceptable solutions to issues. Such solutions may also evolve over time when agreed upon by the parties involved. Integrating sciences into this dynamic social process and utilize modern technologies to facilitate communications and problem solving is the grand challenge we face as university researchers and technology transfer professionals. As a boundary organization, our objective is to be uniquely positioned to work across disciplinary boundaries and bring advanced sciences and technologies into decision makers' hands. Since there is a large gap between academic research and real world operational applications, bridging this gap and streamlining research and the technology transfer process is a major task for IWR as a boundary organization. The efficient and effective utilization of modern technologies such as



advanced Information and Communication Technology (ICT), GIS and numerical modeling is the key to achieve this objective.

- (3) Develop decision support systems that provide support for knowledge users to make more informed decisions based on input from the knowledge generators. As we move from traditional PC-based computing era to a new Internet-based cloud computing age with millions of mobile computing devices coming online at an accelerated rate, we need to conduct further detailed research on how we can develop a new generation of water resources decision support and knowledge systems that can take advantage of recent advances in cyber infrastructure, social networking, geospatial technologies and numerical modeling and associated scientific visualization technologies. To implement this new generation of systems, we need to analyze the needs of different target audiences such as federal, state and local government agencies, NGOs, various environmental organizations and the general public. As a boundary organization, it's critically important that we bring environmental knowledge producers and consumers together under the same overarching umbrella and provide tools for them to work together in a mutually beneficial manner. We need to understand their needs and concerns and address them appropriately.
- (4) Guide development of this new bridging structure through an external advisory body, representing a cross-section of users and scientific groups. This advisory body will have integrative and dynamic roles in providing guidance and ideas to communities of users. The scientists involved will provide connections to clusters of water expertise from the following: multiple units within CANR, such as the Center for Water Sciences and Department of Biosystems and Ag Engineering; other colleges, such as Natural Science and Civil and Environmental Engineering; and, external partners including the USGS Great Lakes Science Center, the Nature Conservancy and others.
- (5) Provide an inclusive environment to facilitate a sense of trust among the knowledge users so they can effectively interact with the knowledge generators, creating an atmosphere and functionality where there is successful communication, translation, mediation, and adaptive process outcomes.
- (6) Actively inform and partner with NGOs and other funding agencies such as EPA, GLPF (Great Lakes Protection Fund), US Army Corps of Engineers, etc., to aid in acquiring support of IWR activities. These partnerships will help to add new funding sources to IWR's existing broad portfolio of funders to facilitate an expanding base of fiscal support.

Literature Review

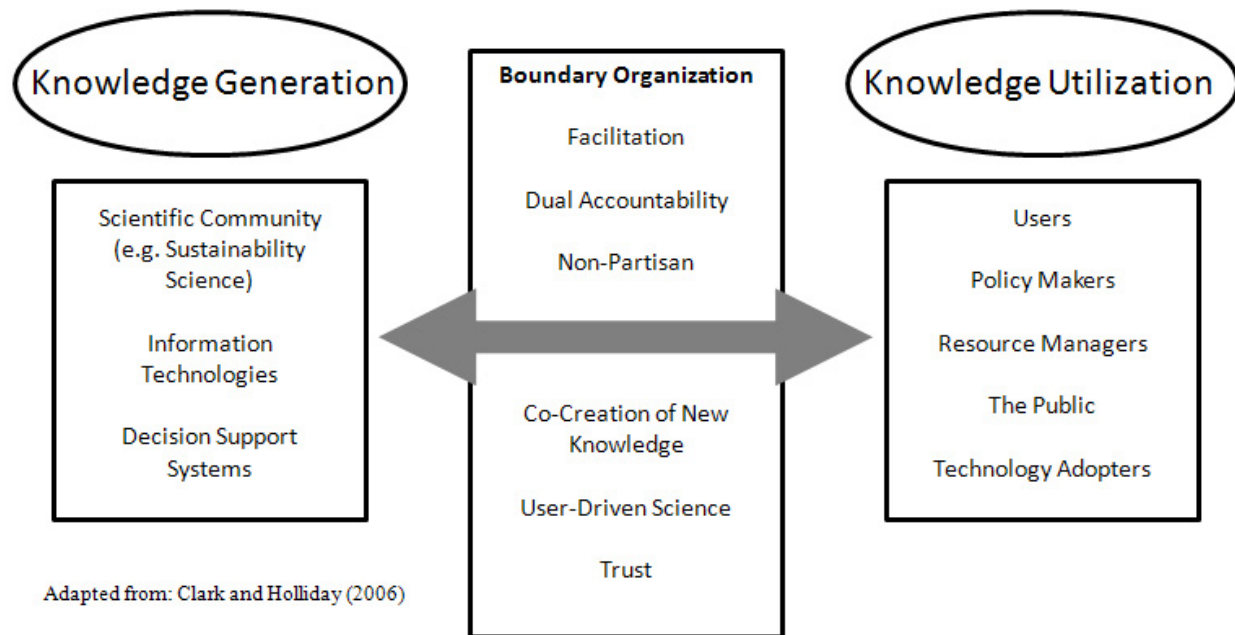


Figure 1. Boundary organization: Linking knowledge with action

All social, economic and environmental factors in a watershed need to be considered in a holistic approach to determine proper actions to manage water resources (Heathcote 1998; Gregersen et al., 2008). Watershed management often involves multiple stakeholders with conflicting interests. These stakeholders can have radically different perceptions of the problems and potential trade-offs associated with finding solutions because of dynamic social, economic, and political factors as well as biophysical complexities of water resources issues. This complex nature of water resource management and other related issues, such as global climate change or health issues, is often referred to in the scientific community as wicked problems (Batie 2008). These types of problems are so named because they are usually difficult to solve due to their complexities and changing nature and often may create other problems as the initial ones are being addressed.

Research on wicked-type problems suggests that a comprehensive knowledge system sustained by a boundary organization is essential (Cash et al., 2003). Boundary organizations act as intermediaries between science and policy because they fulfill or possess: 1) specialized roles within the organization for managing the boundary; 2) clear lines of responsibility and accountability to distinct social arenas on opposite sides of the boundary; and 3) a forum in which information can be co-created by interested parties (Cash et al., 2003). Ingram and Bradley (2006) define boundary organizations as those situated between different social and organizational worlds, such as science and policy. Guston (2001) list three conditions often attributed to successful boundary organizations. “First, they must provide incentives to produce boundary objects, such as decisions or products that reflect the input of different perspectives. Second, they involve participation from actors across boundaries. Third, they have lines of accountability to the various organizations spanned by the boundary organization.” According

to Batie (2008), adaptive and inclusive management practices are essential to the functioning of boundary organizations, and Ruttan et al. (1991) suggests that boundary organizations serve as a bridging institution and help to link suppliers and users of knowledge.

One way to further the efforts of boundary organizations, particularly with wicked problems, is to provide tools to assist with good decision-making using science-based data. Spatial Decision Support Systems (SDSS) are a type of computer system that combine the technologies of Geographic Information Systems (GIS) and DSS to assist decision-makers with problems that have spatial dimensions (Walsh 1993). SDSS are developed to integrate data, knowledge, and modeling results to identify, evaluate, and recommend alternative solutions to spatially distributed problems (Djokic, 1996; Prato and Hajkowicz, 1999). A SDSS focuses on a limited problem domain, utilizes a variety of data, and brings analytical and statistical modeling capabilities to solve the problems. It further depends on graphical displays to convey information to the users. It can be adapted to decision-maker's style of problem solving, and can easily be extended to include new capabilities as needed (Densham et al. 1989, Armstrong et al. 1990).

In natural resource management, SDSS have proven to be effective in a variety of applications such as flood prediction (Al-Sabhan et al., 2003) and conservation program management and best management practices assessment (Rao et al., 2007). Al-Sabhan et al. (2003) argued that a web-based hydrologic modeling SDSS can help solve problems such as limited accessibility by non-experts and the public; lack of collaboration support; and costly data acquisition and communications. They further indicated such system can offer openness, user friendly interface, transparency, interactivity, flexibility, and fast communication and be directly accessible to a broad audience including decision makers, stakeholders and the general public.

Objectives

- (1) Reorganize IWR to more effectively link knowledge with action, i.e., connecting knowledge generation and local applications by becoming an appropriately structured boundary organization.
- (2) Actively be involved in leading, demonstrating and evaluating the co-creation process through numerous specific activities involving “wicked” problems.
- (3) Develop decision support systems that provide support for knowledge users to make more informed decisions based on input from the knowledge generators.
- (4) Guide development of this new bridging structure through an external advisory body, representing a cross-section of users and scientific groups.
- (5) Provide an inclusive environment to facilitate a sense of trust among the knowledge users so they can effectively interact with the knowledge generators, creating an atmosphere and functionality where there is successful communication, translation, mediation, and adaptive process outcomes.
- (6) Actively inform and partner with NGOs and other funding agencies to aid in acquiring support of IWR activities. These partnerships will help to add new funding sources to IWR's existing broad portfolio of funders to facilitate an expanding base of fiscal support.

Plans to Disseminate Information from Stated Research

IWR has effectively worked with a variety of organizations and audiences. This has allowed IWR to build a diverse network of partners. As a complicated and wicked problem, effective water resource management requires solutions from the broad economic sectors it affects. With partners from the university, government, non-government, and private sectors, IWR will receive the input needed to reorganize itself as a boundary organization, bridging the gaps between each of the sectors. IWR will work with its partners and internally to co-create solutions to the complex problems posed by water resource management and disseminate this information through its well established technology transfer program, as well as through its decision support systems, regional networking, social networks and facilitation capabilities. Advisory body inputs will be critically important in defining targets, timelines, and expected impacts. This reorganization can evolve largely within our existing financial and personnel structures.

References

- Al-Sabhan W., M. Mulligan and G. A. Blackburn. 2003. A real-time hydrological model for flood prediction using GIS and the WWW. *Computers, Environment and Urban Systems*, 27(1): 9-32.
- Armstrong, M. P., and Densham, P. J. 1990. Database Organization Strategies for Spatial Decision Support Systems. *International Journal of Geographical Information Systems*, 4(1): 3-20.
- Bartholic, J., Y. Shi, K. Maredia, S. Seedang, J. MacDonagh-Dumler. 2010. Institute of Water Research and Institute of International Agriculture, Michigan State University, "Characteristics of an Action Plan for Addressing Emerging Issues in Water Management for Sustainable Agriculture in South Asia Region." Submitted to the Central Soil & Water Conservation Research & Training Institute Research Centre, India for inclusion in Proceedings from the Indo-US Workshop on Emerging Issues in Water Management for Sustainable Agriculture in South Asia Region, December 10-12, 2009, in Udthagamandalam, Tamil Nadu, India. In Press.
- Batie, Sandra. 2008. Wicked Problems and Applied Economics. *Amer. J. Agr. Econ.*, 90 (5): 1176–1191, DOI: 10.1111/j.1467-8276.2008.01202.x
- Cash, D.W., W.C. Clark, F. Alcock, N.M. Dickson, N. Eckley, D.H. Guston, J. Jäger and R. B. Mitchell. 2003. Knowledge systems for sustainable development. *PNAS*, 100 (14): 8086–8091.
- Clark, W. and L. Holliday. 2006. Linking Knowledge with Action for Sustainable Development. The Role of Program Management. Workshop Summary, Roundtable on Science and Technology for Sustainability, Policy and Global Affairs. National Research Council of the National Academies. Washington, DC; National Academies Press.
- Densham, P. J., Goodchild, M. F. 1989. Spatial Decision Support System: A Research Agenda. *Proceedings of GIS/LIS '89*, Florida, pp. 707-716.
- Djokic, D. 1996. Towards general purpose spatial decision support system using existing technologies. In: *GIS and Environmental Modeling: Progress and Research Issues*. GIS World Books, Ft. Collins, CO.



- Gregersen, H., Folliott, P., Brookes, K. 2008. Integrated Watershed Management: Connecting People to their Land and Water. Cabi Publishing. 2008.
- Guston, D.H. 2001. "Boundary Organizations in Environmental Policy and Science." *Science, Technology and Human Values*, 26(4): 399–408.
- Heathcote I. 1998. Integrated Watershed Management: Principles and Practice. Wiley. 1998.
- Ingram H., and B. Bradley. 2006. "Water Sustainability: Policy Innovation and Conditions for Adaptive Learning." Paper presented at the Michigan State University Sustainable Michigan Endowed Project Academy, Dearborn, MI, 18–19 November.
- O'Neil, G., J. Bartholic, Y. Shi. 2010. Institute of Water Research, Michigan State University. "High Impact Targeting Decision Support System for BMPs to Most Effectively Reduce NPS Pollution" presented at the 18th National Nonpoint Source Monitoring Workshop held in Milwaukee, Wisconsin November 16-18. Nov. 17, Session 5-03, In Proceedings on CD, 33 pp.
- O'Neil, G., L. Theller, Y. Shi, J. Bartholic, B. Engel. 2010. The Swan Creek Watershed Management System," presented by O'Neil at the TMDL 2010: Watershed Management to Improve Water Quality ASABE Conference, Nov. 14-17 in Baltimore, MD. In Press
- Prato, T. and S. Hajkowicz. 1999. Selection and sustainability of land and water resource management systems. *Journal of the American Water Resources Association*, 35(4): 739-752.
- Rao, M., Guoliang Fan, J. Thomas, G. Cherian, V. Chudiwale and M. Awawdeh. 2007. A web-based GIS Decision Support System for managing and planning USDA's Conservation Reserve Program (CRP). *Environmental Modelling & Software*, 22(9):1270-1280.
- Ruttan, V.W., D.E. Bell, and W.C. Clark. 1994. "Climate-Change and Food Security—Agriculture, Health and Environmental Research." *Global Environmental Change-Human and Policy Dimensions*, 4(1):63–77.
- Steinman, A.D., J.R. Nicholas, P. Seelbach, J. Allan, and F. Ruswick. 2010. The role of science in developing policy for the use of groundwater in the state of Michigan. *Water Policy*. DOI:10.2166/wp.2010.047.
- Walsh, M. R. 1993. Towards Spatial Decision Support Systems in Water Resources. *Journal of Water Resource Planning and Management*, 119(2): 158-169.

Principle Findings and Significance

Extensive investigation and research is needed to achieve effective coupling of human management needs with geospatial databases and decision support systems to assist better decision-making. Multiple research funding opportunities exist to support linking understanding of various phases of the hydrologic cycle with impacts on water use, management, and conservation. As a result, outstanding opportunities to develop scientific water management skills and techniques for the 21st Century are clearly within reach.

Research and Development: The *Water Resources Partnership* is a major effort with support and involvement from units across the University campus with the Michigan Department of Environmental Quality as the key external funding partner. At this time the project is a four year effort funded at 1.5 million dollars. [This project is inclusive in nature relative to Michigan's Department of Environmental Quality (MDEQ) partners and clients interested in the products.] Campus partners provide fundamental inputs relative to new frontiers such as computational thinking which is dependent on new computational capabilities, web technologies, and advanced GIS web-based delivery systems. Also, MSU's Extension and Outreach and Engagement units are involved. Fundamentally this project facilitates the discovery of new approaches for integrating advanced multi-scale modeling with intuitive visual and interactively enhanced outputs. Products from this activity are also used in other active projects, with those projects in turn providing general feedback into the Water Resources Partnership.

Our strong research base is enhanced by our involvement in regional/national USDA Hatch multi-state research projects. One such project, MICLO4064/W2190 entitled *Water Policy and Management Challenges in the West* (from W1190), addresses water policy and economic research and involves researchers across the U.S. Another research project, MICLO4052/S1042 *Modeling for TMDL Development and Watershed Based Planning and Management and Assessment*, involves hydrologic and non-point source (NPS) modelers with a specific focus on total maximum daily loading (TMDL's) and general NPS reduction strategies.

Specific Projects Conducted

1. An Overview of Activities
2. "Water Policy and Management Challenges in the West" for IWR's part contrasts Water Law/Management between the Eastern and Western United States. This is annual report of progress.
3. "Modeling for TMDL Development and Watershed Based Planning, Management and Assessment" Research Report incorporates recent progress on a variety of IWR's research projects.
4. "Web-based Networked Neighborhoods for Eco-Conservation" funded by the Great Lakes Protection Fund.



1. An Overview of Activities:

Outputs

General Background: The IWR at MSU is responsible for coordinating research and educational programs on surface water and ground water quality and quantity. Established in 1961 the Institute addresses multi-disciplinary issues arising from the dynamic interaction of land and water resources and strengthens MSU's commitment to finding effective solutions to contemporary water resource Problems. The Institute has developed water-related programs across a wide spectrum of issues. Ongoing support from the USGS, Department of interior, Michigan Ag-Bio Research and MSU Extension helps fund important research and outreach on water issues with regional land national significance. The Institute's goal is to provide the most accurate and complete information on contemporary land and water issues to citizens, stakeholders, government agencies, and resource managers. To achieve this goal, the Institute consistently collaborates and forges partnerships with other research and resource conservation organizations and agencies. The result of these collaborations is the development of science-based information for use by decision makers faced with complex water issues. The increasing use of information technologies and decision-making is a fundamental part of the Institute's mission in the 21st Century.

Programs: The Institute functions in a coordinating role to support education, research, and outreach through partnerships with University departments, agencies, and organizations in the board water arena. Efforts focus on three major areas: (1) integrated watershed systems including both surface and ground-water; (2) extended education and outreach; (3) networking infrastructure.

Integrated Watershed Systems: The Institute continues to development decision support systems that utilize data, models, and spatial analysis to provide an increased understanding of land-water relationships. These systems are made available through interactive web based GIS/graphic tools.

Some examples are highlighted below.

General Programs: We believe the above brief description of the Institute's program makes it clear that our operation, with a budget in excess of \$1 million a year, continually works on developing innovative tools using new technologies to assist with improved understanding and assessment of how human activities on the landscape can influence the natural system with emphasis on water quality and quantity. Several examples to highlight these programs follow. We currently have a \$225,000 three-year active project funded by the C.S. Mott Foundation (MOTT) through The Nature Conservancy (TNC) to work in the Saginaw Bay developing a variety of tools to enhance ecological services from the landscape. This GLRI proposed project is of particular importance as it will be a companion effort with the TNC/MOTT project but more importantly, we can tap into a whole array of understanding ecological outcomes from improved water quality resulting from better land-use practices. It is critically important to realize that farmers and other owners of land are likely more motivated to make improvements that will impact the environment; i.e. fish habitat, birds, and recreational use, etc. Thus we can incorporate knowledge from the TNC/MOTT project along with spatial system products, into the



education and outreach components of this proposed project. Other examples of IWR work involves an NRCS CIG grant in which we partnered with the Michigan Department of Agriculture and supported half of three conservation technician salaries at three different County Conservation Offices. They were an integral part of the CIG project both at the state and local levels which led to the successful development and subsequent use of the High Impact Targeting (HIT) system now recommended by MDEQ and used by NRCS in many of their activities including prioritization of Farm Bill financial and technical assistance dollars. We have also worked on multiple projects with the Great Lakes Protection Fund. These projects facilitated the early conceptualization and development of the now highly successful Water Withdrawal Assessment Tool developed by IWR in cooperation with many others. This web-based tool is utilized throughout the state for on-line registering of new high-capacity wells. More recently the Great Lakes Protection Fund funded IWRs Networked Neighborhoods project that incorporates new social networking concepts and web-based interactive technologies allowing individual homeowners to easily upload their BMPs (rain barrels, rain gardens, etc.). Since the BMPs are all geo-positioned by the homeowners as they enter the data, the impact that these multiple practices have in any given watershed can be summarized within sub-watersheds providing feedback to the citizens on the combined positive impact they have had in reducing runoff and nutrient loads.

These are but a few of IWRs more recent activities each having their own components of outreach and dissemination incorporated into the Institutes ongoing technology transfer and outreach efforts.

Programs Federal: The following are specific examples of federal programs for which IWR has been funded. Multiple grants from the same agency are emphasized as over time we have developed successful partnerships by consistently meeting their expectations and effectively reported both on the program and fiscal responsibility.

A key series of federal grants to the IWR have been from the U.S. Geologic Survey with several consecutive five-year grants each approximately \$500,000. Nearly half of these funds were provided for external grants to faculty at MSU and universities around the state. A significant portion of funds of roughly 30% went for technical assistance plus outreach and education. A second grant of significant size was a Comprehensive Innovation Grant, 2006-2009 for \$82,000.

This grant was in partnership with the Michigan Department of Agriculture. Three half-time positions were funded at three County Conservation District offices. This was a very productive and successful grant that developed technology tools for evaluation of high erosion areas (sediment delivery to streams) and suggested cost effective improvements (BMPs) and farm level action.

Outcomes/Impacts

The results of this three year project yielded what is now termed the High Impact Targeting (HIT) tool to calculate the highest eroding fields and watersheds. This system is now available throughout the Great Lakes Basin. Michigan Department of Environmental Quality's 319 program is suggesting the HIT system for use in the development of 319 watershed management plans and the system is being used by NRCS for prioritizing higher payments for practices to be placed in the highest risk locations determined with the HIT system. The Army Corps of



Engineers through their 516(e) program have funded five projects from 2004 through the present to guide the development of modeling techniques for predicting soil erosion (sediment) loads to the Great Lakes. Subsequently they supported making this information available via the web for users throughout the basin. Because of the project success and providing timely reports, the work continues. Another project that has received multiple funding, in this case from EPA to MDEQ as part of the 319 program for a Social Indicators project. Three phases of this project was funded over a three-year period. This program is now being utilized by all states in the EPA Region 5 area.

Publications

None at this time.

2. “Water Policy and Management Challenges in the West” for IWR’s part contrasts Water Law/Management between the Eastern and Western United States. This is annual report of progress.

Nonpoint source pollution poses particular challenges to tracking water quality improvements in watersheds. Demonstrating improvements through traditional measures have not proven successful due to complex variables within watersheds and delays in response to applied management strategies. Social data can be used as a surrogate to traditional monitoring to identify changes in peoples behavior and attitudes that lead to improved water quality. However, due to the need for consistent measures and indicators for summarizing social data, using a practical framework and system to manage these indicators is crucial. The Social Indicator Data Management and Analysis (SIDMA) system was developed to provide a practical means for project management and administration to easily build and standardize social surveys, track progress, and summarize results in targeted watersheds.

In support of Coca-Cola and The Nature Conservancys (TNC) desire to protect Michigans Paw Paw River and remain water neutral, we developed a suite of maps and modeled outputs that display optimal locations for protection and improvement of water quality and quantity in the Paw Paw River watershed.

Previous work by Michigan TNC staff and Michigan State University (MSU) partners has resulted in a tool to quantify the impacts of groundwater pumping and surface land use on a groundwater aquifer. This framework allows for groundwater recharge (replenishment) to be calculated through spatial land use changes (e.g. conversion of conventional tillage to no-till, conversion of agricultural land to grassland or wetland restoration). Here we propose to apply this tool to the Paw Paw River Watershed, with the specific outcome of more efficiently targeting our outreach efforts to farmers, for the benefit of water quantity and quality within the watershed.

The optimization maps are the product of three tool outputs; Michigans Water Withdrawal Assessment Tool (WWAT); High Impact Targeting (HIT); and Soil and Water Assessment Tool (SWAT). The idea behind the optimization maps is to individually identify and map areas of particular interest within the watershed such as: high sediment loadings, agricultural row crops, water withdrawal, and groundwater recharge by soil groups. Once areas were modeled and identified, they were assigned weighting within a 30x30 meter grid cell. The weightings were summarized to provide rankings for priority location specific mapping of the key water balance factors. In this project we used the USDA-ARS SWAT and the USDA-NASS Cropland Data Layer to estimate the amount of annual irrigation water that could be used for irrigated agriculture (maize) across current row crop agriculture in the state of Michigan. The model was run on all row crop soil types across the state using site specific long term weather data from five locations. The results were aggregated to the watershed level that is used by the WWAT managed by the MI Department of Natural Resources and Environment.



Outcomes/Impacts

The SIDMA website is the first system created to both manage social data related to water quality improvement and offer tools for users to build standardized social surveys. These functions allow project managers and administrators funded through the EPA's 319 program to demonstrate improvements in watersheds in new and innovative ways. In addition, administrators can easily search and report on the status of any of these projects across a region, reducing time and resources typically involved in facilitating these requests.

Online Groundwater Recharge Calculator: The online groundwater recharge calculator estimates the change in recharge to an aquifer based on land use/cover change and acres of land converted. The interface utilizes a map section and calculator section. The map section is built on Microsoft Bing Maps and displays the 12 digit HUC watershed boundaries, streams, and soil groups. The map interface works best with Mozilla FireFox. The user can zoom into parcel of land they are interested in and click the Create New Parcel button at the top map. The user can then single click on the corners of the property for which they wish to make land use/cover changes (double click when finished). The map will automatically calculate the size the parcel and soil type(s), and then open the calculator interface.

In the calculator interface, the user can enter the current land use/cover and the proposed land use/cover. If the soil type from the selected parcel is a single soil type, and not comprised of multiple soils, the interface will select that soil group; if there are multiple soils groups, the user will have to choose a dominant type. Once these parameters are all chosen, the user clicks the Calculate button. This sends the parameters to a recharge look up table produced by the SWAT model. The results are displayed in graphical and numeric form displaying the change in groundwater recharge.

A project titled Refining the Water Needs and Availability for Michigans Agriculture, provides broader yet location specific mapping of the key water balance factors. Never before has a thorough statewide assessment been conducted and presented of water balance factors with specific emphasis on water availability and needs at a water catchment level. This information is critically important and being utilized by the irrigation industry, seed corn growers, plus other agricultural producers. The information generated supports both broader statewide conceptual planning and detailed local consideration of water availability related to present and growing irrigation demands. We have used the results of this study to educate staff from the state agencies on irrigation and groundwater recharge in an agricultural setting. The study has given a good indication of what the long term irrigation demands are spatially across the state and where new irrigation demands are likely to occur.

Publications

Bartholic, J., W. Northcott, S. Miller, J. Asher, S. Seedang, S. Gasteyer, and J. Andresen. 2010. Refining the Water Needs and Availability for Michigans Agriculture from a Spatial and Temporal Perspective, Institute of Water Research, Michigan State University, 5 pp.

Isely, E, P. Isely, S. Seedang, K. Mulder, A. Steinman, and K. Thompson. 2010. Addressing the Information Gaps Associated with Valuing Green Infrastructure in West Michigan:



- Integrated Valuation of Ecosystem Services Tool (INVEST). *Journal of Great Lakes Research* 36(3):448-457
- Seedang, S. and P. Norris. 2010. Water Use in Michigan. Technical paper. Michigan Agricultural Experimental Station.
- Adelaja, S. Y. Hailu, A. Tekle and S. Seedang. 2010. Evidence of Land Hoarding Behavior in U.S. Agriculture. *Agricultural Finance Review* 70(3) 377-398.
- Seedang, S., S. Batie, and M. Kaplowitz. 2010. Using Bio-Physical Information to Structure a Ground Water Conservation Credit Program (draft manuscript paper).
- Seedang, S., P. Norris, and J. Bartholic. 2010. The Role of Water Conservation Technology, Economics, and Institutions for Reducing Water Use Conflicts, Michigan Case Study (Proceedings abstract). The American Water Resources Association Annual Conference, Seattle, WA, November 9-12, 2009.
- Bartholic, J., Y. Shi, K. Maredia, S. Seedang, J. MacDonagh-Dumler. 2010. Institute of Water Research and Institute of International Agriculture, Michigan State University, Characteristics of an Action Plan for Addressing Emerging Issues in Water Management for Sustainable Agriculture in South Asia Region. Submitted to the Central Soil & Water Conservation Research & Training Institute Research Centre, India for inclusion in Proceedings from the Indo-US Workshop on Emerging Issues in Water Management for Sustainable Agriculture in South Asia Region, December 10-12, 2009, in Udhagamandalam, Tamil Nadu, India.
- ONeil, G., L. Theller, Y. Shi, J. Bartholic, B. Engel. 2010. The Swan Creek Watershed Management System, presented by ONeil at the TMDL 2010: Watershed Management to Improve Water Quality ASABE Conference, Nov. 14-17 in Baltimore, MD.
- Shi, Y., J. Bartholic. 2010. Institute of Water Research, Michigan State University, .Managing Water Resources through Virtual Organizations. Proceedings from the Indo-US Workshop on Emerging Issues in Water Management for Sustainable Agriculture in South Asia Region, December 10-12, 2009, in Udhagamandalam, Tamil Nadu, India.
- Shi, Y., J. MacDonald-Dumler, J. Bartholic, G. ONeil, J. Asher. 2010. Institute of Water Research, Michigan State University. Decision Support Tools for Watershed Management . A United States Experience. Proceedings from the Indo-US Workshop on Emerging Issues in Water Management for Sustainable Agriculture in South Asia Region, December 10-12, 2009, in Udhagamandalam, Tamil Nadu, India.
- Wolfson, L. G. 2010. Rain Barrels, Rain Gardens, Green Roofs, and Porous (Permeable) Pavement. Fact Sheet Series. Networked Neighborhoods for Eco-Conservation Online. Accessible at: <http://www.networkedneighbors.org/>

Participants:

Individuals, organizations, etc. are incorporated in the Outcomes section of this report.



Target Audiences:

Individuals, organizations, etc. are incorporated in the Outputs and Outcomes sections of this report.

Project Modifications:

Nothing significant to report during this reporting period.



3. “Modeling for TMDL Development and Watershed Based Planning, Management and Assessment” Research Report incorporates recent progress on a variety of IWR’s research projects.

Develop Tools: Nonpoint source pollution poses particular challenges to tracking water quality improvements in watersheds. Demonstrating improvements through traditional measures have not proven successful due to complex variables within watersheds and delays in response to applied management strategies. Social data can be used as a surrogate to traditional monitoring to identify changes in peoples behavior and attitudes that lead to improved water quality. However, due to the need for consistent measures and indicators for summarizing social data, using a practical framework and system to manage these indicators is crucial. The Social Indicator Data Management and Analysis (SIDMA) system was developed to provide a practical means for project management and administration to easily build and standardize social surveys, track progress, and summarize results in targeted watersheds.

Decision support systems for optimally managing the landscape of our Great Lakes watersheds have advanced significantly in recent years. Several approaches have been used in specific case studies. One such system known as High Impact Targeting (HIT) has evolved over the past several years and can now provide guidance to resource/watershed managers across the basin. With assistance and support from the Army Corps of Engineers 516e program and the USDA-NRCS-CIG program, this systematic approach toward identification and prioritization of highest contributing sediment locations (watershed down to sub-field scales) has been evaluated and enhanced. The HIT plus system is now available across the Great Lakes Basin. The system utilizes a spatially explicit sediment loading model that combines a soil-erosion model called RUSLE (Revised Universal Soil Loss Equation) and a sediment delivery ratio model called SEDMOD (Spatially Explicit Delivery Model). The system has been extensively evaluated at the County Conservation District office level and system outputs have been incorporated locally into the NRCS county level Tool Kit analysis system.

Gully erosion is an important sediment source in the environment. Gullies provide effective links for transporting runoff and sediment from uplands to valley bottoms and stream channels. Many damages done to watercourse and properties by runoff from agricultural land are related to gully erosions. In the past, the Institute of Water Research (IWR) sediment modeling tool was mostly focused on sheet erosion over agricultural landscapes. To enhance our capabilities for comprehensive sediment modeling, IWR recently applied technique developed by USDA-ARS to the Root River watershed in MN for a pilot study. This method uses a Compound Topographic Index (CTI) as a predictor of ephemeral gully potential. CTI can be calculated in a GIS environment and is also programmed into the latest version of the AnnAGNPS software. The results we got for potential gully erosions in Root River watershed show this is a promising technique and can be utilized in the Great Lakes region based on high resolution DEMs(2-4 meters).



Outcomes/Impacts

A suite of decision support and learning web-based tools have been developed that are being used throughout the state and within the Great Lakes region to enable agencies and users to make more informed decisions concerning key environmental issues or practices. The State Department of Environmental Quality has recommended their use with watershed planning grants, and the Michigan NRCS is using one of these systems to guide their process in developing priority watersheds. Included are High Impact Targeting (HIT) (www.iwr.msu.edu/hit2) which prioritizes areas, at multiple scales, for optimal soil erosion and sediment loading reduction; Social Indicators Data Management and Analysis system (SIDMA) (www.iwr.msu.edu/sidma), a part of a larger multi-state project to measure social indicators as proxies for water quality; and Networked Neighborhoods for Eco-Conservation (www.networkedneighbors.org) which uses social networking and mapping technology to link people together with common goals of improving the environment in the Great Lakes Basin or their watershed.

The Social Indicators Data Management and Analysis (SIDMA) website is the first system created to both manage social data related to water quality improvement and offer tools for users to build standardized social surveys. These functions allow project managers and administrators funded through the EPA 319 program to demonstrate improvements in watersheds in new and innovative ways. In addition, administrators can easily search and report on the status of any of these projects across a region, reducing time and resources typically involved in facilitating these requests.

The High Impact Targeting (HIT) system is being utilized in watershed planning funded by the EPA 319 watershed program. The HIT system has aided in watershed planning by defining problematic agricultural areas in the watershed. Also, the system aids in the prioritization of actions to be taken in the implementation portion of the watershed improvement process. Estimates of sediment reduction from BMP implementation can be calculated and accumulated from field to watershed to sub-basin levels.

Facilitate Usability: These new technologies are allowing local users access to field level interactive intelligent guidance for conservation planning and practice selection. These systems can greatly improve efficiency and effectiveness for field technicians and land owners with identifying problematic fields, assessing BMPs, and simultaneously recording subsequent actions. One such system currently being adapted for hand-held and tablet technology delivery is High Impact Targeting (HIT), which is an action support tool at the watershed and field level for aiding conservation decisions. This hand-held and tablet technology delivery tool can provide greater cost-effective decisions to reduce the levels of sediment and nutrients reaching streams and lakes.

Publications

- Bartholic, J., W. Northcott, S. Miller, J. Asher, S. Seedang, S. Gasteyer, and J. Andresen. 2010. Refining the Water Needs and Availability for Michigans Agriculture from a Spatial and Temporal Perspective, Institute of Water Research, Michigan State University, 5 pp.
- Isely, E, P. Isely, S. Seedang, K. Mulder, A. Steinman, and K. Thompson. 2010. Addressing the Information Gaps Associated with Valuing Green Infrastructure in West Michigan: Integrated Valuation of Ecosystem Services Tool (INVEST). *Journal of Great Lakes Research* 36(3):448-457
- Seedang, S, P. Norris, and J. Bartholic. 2010. The Role of Water Conservation Technology, Economics, and Institutions for Reducing Water Use Conflicts, Michigan Case Study (Proceedings abstract). The American Water Resources Association Annual Conference, Seattle, WA, November 9-12, 2009.
- Bartholic, J., Y. Shi, K. Maredia, S. Seedang, J. MacDonagh-Dumler. 2010. Institute of Water Research and Institute of International Agriculture, Michigan State University, Characteristics of an Action Plan for Addressing Emerging Issues in Water Management for Sustainable Agriculture in South Asia Region. Submitted to the Central Soil & Water Conservation Research & Training Institute Research Centre, India for inclusion in Proceedings from the Indo-US Workshop on Emerging Issues in Water Management for Sustainable Agriculture in South Asia Region, December 10-12, 2009, in Udhagamandalam, Tamil Nadu, India.
- ONeil, G., J. Bartholic, Y. Shi. 2010. Institute of Water Research, Michigan State University. High Impact Targeting Decision Support System for BMPs to Most Effectively Reduce NPS Pollution, presented at the 18th National Nonpoint Source Monitoring Workshop held in Milwaukee, Wisconsin November 16-18. Nov. 17, Session 5-03, In Proceedings on CD, 33 pp.
- Shi, Y., J. Bartholic. 2010. Institute of Water Research, Michigan State University. Managing Water Resources through Virtual Organizations. Proceedings from the Indo-US Workshop on Emerging Issues in Water Management for Sustainable Agriculture in South Asia Region, December 10-12, 2009, in Udhagamandalam, Tamil Nadu, India.
- Shi, Y., J. MacDonald-Dumler, J. Bartholic, G. ONeil, J. Asher. 2010. Institute of Water Research, Michigan State University. Decision Support Tools for Watershed Management. A United States Experience. Proceedings from the Indo-US Workshop on Emerging Issues in Water Management for Sustainable Agriculture in South Asia Region, December 10-12, 2009, in Udhagamandalam, Tamil Nadu, India.
- Stepenuck, K., L. Wolfson, B. Liukkonen, J. Iles, and T. Grant. 2011. Volunteer Monitoring of E. coli in Streams of the Upper Midwestern United States: A Comparison of Methods. *Environmental Monitoring and Assessment* 174:625-633.
- Wolfson, L. 2010. Harmful Algal Blooms on the Rise. 2010. *Lake Effect: Vol. 2*. February 2010. Michigan Chapter, North American Lake Management Society. Pages: 69.

Wolfson, L. G. 2010. Rain Barrels, Rain Gardens, Green Roofs, and Porous (Permeable) Pavement. Fact Sheet Series. Networked Neighborhoods for Eco-Conservation Online. Accessible at: <http://www.networkedneighbors.org/>

Participants:

Individuals, organizations, etc. are incorporated in the Outcomes section of this report.

Target Audiences:

Individuals, organizations, etc. are incorporated in the Outputs and Outcomes sections of this report.

Project Modifications:

Nothing significant to report during this reporting period.

4. Web-based Networked Neighborhoods for Eco-Conservation”





Networked Neighborhoods for Eco-Conservation Online

Great Lakes Protection Fund- IT Transparency

Final Report
(Grant Proposal #884)

INSTITUTE OF WATER RESEARCH AT MICHIGAN STATE UNIVERSITY

2012

Authored by: Jeremiah Asher

Co-authors: Jeff Grabill, Cliff Lampe, and Lois Wolfson

Reviewers: Cindy Brewbaker and Glenn O'Neil

Networked Neighborhoods for Eco-Conservation Online

Great Lakes Protection Fund- IT Transparency

Executive Summary

Networked Neighborhoods for Eco-Conservation Online (NECO) is web-based application that uses mapping and social networking concepts to stimulate the adoption of green practices and track their implementation in neighborhoods throughout the Great Lakes Basin (www.networkedneighbors.org). In the three year duration of the project, the NECO website drew 200 registered users who mapped over 1,000 practices into NECO and reduced an estimated 952 lbs of nitrogen, 298 lbs of phosphorus, 10.7 tons of suspended sediment, and 472.7 billion colonies of fecal coliform from entering nearby rivers, lakes, and streams.

Survey results indicated users were motivated to adopt practices and share them with others after using NECO. Registration data also confirms this, the second most popular avenue for people coming to NECO was through hearing about it from a friend. However, interviews with partnering organizations describe little behavior change in adopting green practices by the groups in which they service. IWR concluded the adoption of green practices is occurring but currently may be too small to see at the watershed scale.

There is a steady upward trend in the amount of new users joining NECO up 44% from one year ago. Although it was anticipated that a greater number of users would be registered on the site, the projected trend indicates close to 350 registered users by this time next year. Overall NECO has been well received. Research shows that when asked to rate a series of words describing the NECO website the majority of users indicated the site was *organized*, *useful*, and *informative*. Since the site has had very positive reviews, it is believed that the lower than anticipated number of registered users is likely due to the marketing strategy applied. This theory is also supported by data which indicated that only 7% of the people surveyed had heard about NECO.

It was inconclusive to what extent NECO played in fostering competitiveness among users since some who adopted a practice may have been influenced by other factors outside of NECO. Surveys indicated that 38% of people agreed or strongly agreed that they were likely to adopt a green practice because their neighbor had. It is hypothesized that the highly used mapping interface encouraged this type of competitive adoption by visually presenting neighboring practices. In contrast, the specific tools designed to create and compare individual groups received minimal use.

Project Overview

Networked Neighborhoods for Eco-Conservation Online (NECO) is web-based application that was developed to stimulate the adoption of green practices and track their implementation in neighborhoods throughout the Great Lakes Basin (www.networkedneighbors.org). NECO uses both social networking and mapping technologies to link people together with common goals of improving the environment in the Great Lakes Basin, their watershed, or their own backyard. By combining these technologies into an easy to use online interface the Institute of Water Research (IWR) at Michigan State University (MSU) sought to provide tools and information that would encourage individuals to learn about, adopt, and share green practices. While a single individual practice, such as creating a rain garden or filter strip may seem inconsequential, these practices can collectively have a significant impact if they are adopted across an entire watershed or community. The NECO system has aggregated these actions over space and time to demonstrate the collective impact of individual practices on the health of the Great Lakes streams and aquatic ecosystems.

Goals and Hypotheses

The three major goals for the NECO project were to: 1) increase the effectiveness of existing environmental groups and organizations, 2) motivate individuals to adopt green practices, and 3) improve the health of the Great Lakes through the adoption of green practices. The immediate goal of the project was to strengthen, support, and integrate

the current efforts of many environmental organizations by providing geospatial mapping technologies that can track their efforts in local watersheds anywhere in the Great Lakes Basin. The longer term goals were to increase individual adoption of green practices and improve the health of the Great Lakes.

IWR hypothesized that the development and implementation of NECO would:

1. Increase awareness of green practices through web-based information dissemination
2. Motivate individuals to adopt green practices through an interactive web-based system that visually illustrates participation and helps to network individuals through the online community
3. Provide a measurable benefit to the water quality in the study area and Great Lakes Basin through the web-based modeling components

Importance of Green Practices

NECO focuses on four green practices: rain gardens, rain barrels, porous pavement, and green roofs to help improve ecological health of the Great Lakes and its connecting waterways. These practices, along with a variety of others available to NECO users, capture or slow the flow of stormwater runoff from impervious surfaces during heavy rain events. Impervious surfaces from urbanization degrade aquatic ecosystems by altering urban stream hydrology and increasing the flux of pollutants into the stream from storm runoff. Traditional storm sewer systems in urbanized areas were designed to move runoff from streets and into waterways¹. However, this speedy removal eliminates the ability of soils to filter pollutants in the runoff and recharge groundwater. Reduced groundwater recharge can diminish base flow to streams, exacerbating the impact on aquatic ecosystems. Agriculture has also dramatically altered the landscape in the Great Lakes Basin. The Basin contains approximately 23.9 million acres of agricultural land (crop and pasture, NLCD 2001), which has replaced natural land cover types such as wetlands, forest and grassland. Agricultural drainage ditches and a lack of streamside buffers quickly convey runoff, often carrying sediment and fertilizer, to rural streams. Excessive sediment eroded from agricultural land can clog streambeds and disturb fish habitat, while excessive fertilizers in rural streams can cause harmful algal blooms. These issues affecting the Great Lakes Basin are not caused by one single event, but an accumulation of many individual decisions and actions over time.

The Process

NECO was developed by a multi-disciplinary team comprised of social media and digital writing experts from Michigan State University (MSU), along with software developers, geographic information system specialists, outreach specialists, a climatologist, an agricultural engineer, watershed specialists from three states, graduate students, and a variety of other team members.

Partnerships

In an effort to establish strong centers of adoption for NECO, build off of existing on-the-ground efforts, and evaluate the project's effectiveness, IWR developed partnerships with three groups and one individual. The locations for these groups were used as the pilot study areas where NECO was implemented. The organizations were West Michigan Environmental Action Council (WMEAC) in Grand Rapids, MI, Toledo Ohio Rain Garden Initiative in Toledo, OH, Root-Pike Watershed Initiative Network in Racine, WI, and an individual, Ken Freestone, formerly with West Michigan Strategic Alliance in Holland, MI.

IWR worked with each of the partners to determine what financial resources would be needed to help promote the NECO site, host rain garden and rain barrel workshops, and assist individuals and businesses with installations of green practices.

¹ Brabec, E., Schulte, S. and P. L. Richards. 2002. Impervious surfaces and water quality: A review of current literature and its implications for watershed planning. *Journal of Planning Literature*. 6 (4): 499-514.

The partnerships that were developed for the NECO project were vital to its success. The mapping interface clearly shows the clusters of green practices installed around the study areas. These would not have been possible without our partner's contributions, a critical component to enticing new users to come to the website. Research has shown if content is not updated (e.g. people mapping their green practices or participating in the forum), and potential users do not see other users regularly interacting on the site they are less likely to join or contribute².

In the future, IWR would likely add additional partners in areas of the basin not currently represented, which could require additional funding. This type of funding for partnering groups seemed to be instrumental to early adoption of NECO. While there were examples of organizations (Watershed Center at Grand Traverse Bay) adopting NECO without funding through cold calling, presentations, and other outreach methods, greater and faster adoption was accomplished with funding.

Interviews and Surveys

IWR conducted both interviews and surveys at the beginning and end of the project to determine what types of change, if any had occurred and to evaluate the project. Two interviews were led by an expert in user evaluation design and usability. The first was used to examine how the partner organizations conducted their day-to-day business. The result helped the development team with creating an application that fit into the partner's work flow and provided a value added service. The second interview was geared more toward evaluating the success of NECO from the partner's perspective.

The initial survey carried out by an expert in social media and online community design, was used to evaluate the target audience and look at their technical experience, Internet connectivity, and general demographics. This information was used to influence the design and capabilities of the site. The second survey was much broader and captured user opinions, perceptions of the website, its usability and utility, and general attitudes regarding green practices. This survey was used to evaluate the site overall and better understand the attitudes and awareness of green practices by the audience.

The surveys and interviews provided an excellent evaluation of the project and helped to answer some of the initial questions posed by the team. Results from the surveys and interviews can be found in the Project Results section of this report.

User Evaluation Workshops

User evaluation workshops were used to guide the development of the NECO system and ensure that users were able to perform critical functions on the website. The workshops were critical to creating a thoughtful and usable interface design. Since the beginning of the project IWR established a user-guided process that helped center the website design around the user's needs. Three workshops were conducted in East Lansing, MI; Holland, MI; and Toledo, OH, and one webinar was used to allow our partners in Racine, WI to evaluate the system.

The workshops were progressive and built upon each other. The goal was to evaluate 8-10 users in each workshop and document their experience using the system. Each workshop had a set of essential tasks that were centered on the core functions of NECO. The users were representative of our target audiences; homeowners, business, and environmental groups. The evaluation team consisted of two individuals, one that would read the tasks or scenarios to the user, and another to document the path the user took, the amount of time, and whether or not the user was able to complete the task.

The results were compiled and given to the development team to modify or redesign parts of the NECO system that proved difficult to use. In the next user evaluation workshop a complete new set of users participated. Several of the previous tasks and scenarios were evaluated to ensure they were now easier for user to complete. In addition to the previous tasks and scenarios, new ones were developed and tested with this group as well. The same process of

² Lampe, C., & Roth, B. (2012). *Implementing Social Media in Public Sector Organizations*. Paper presented at the iConference '12, Toronto

evaluation, compilation, and modification was executed through the four user evaluations until the system was suitable for public use.

Interface Design

Developing the web-based interface was the most resource intensive task of the project. As previously mentioned there were multiple iterations of the design, guided by the user evaluation workshops. The goal in designing the frontend and mapping interface was to streamline the process of adding a practice to the map and to quickly allow users to perform the most important tasks simply. The entire process including logging into the website, navigating to input screen, selecting a practices, and mapping it, took under one minute. Most of the time involved in this task was in the behind the scene processing which captures soils information, compiled weather data, home watershed, and latitude and longitude coordinates. This information was used to automate data retrieval and calculations, and assist users with inputs for water storage estimates.

There was a half time programmer who coded most of the mapping interface and a part of a full time employees time that directed mapping and interface design layout. One of the graduate assistant mapping programmers departed about three quarters through the project which slowed some development. One change that IWR would make for similar future projects would be to add another part-time programmer for a portion of the development dedicated to the social media components. IWR found it challenging to merge Facebook into NECO to the extent that it had hoped (moving beyond Facebook links and likes). Some of the unseen challenges were that Facebook was still growing and changing during NECO development and APIs (application programming interfaces) for Facebook continued to change. This required the development team to constantly rewrite or modify existing code that allowed the two systems to communicate. This ultimately deterred some development in other areas of the site and extended the amount of resources required to complete overall interface design tasks.

The interface design also included tools/functions that IWR created to test participation, incentives for adoption, and competitive rivalry. They included a forum for sharing information, storm alert system, comparing and ranking of groups and individual's environmental benefits, and a number of techniques that could encourage social participation on the site. The outcomes of these tools/functions are described in the project results section of this report.

Application Rollout

The rollout of the NECO system occurred in two phases. Both were aimed at the general public to begin the development of active NECO user communities. Phase one was deemed a soft rollout, which was limited in scope but highly interactive. It was primarily initiated to determine how users were reacting to the system and gave the developers the opportunity to modify and change strategies prior to the hard rollout.

The soft rollout was advertised at three venues: 1) Michigan State University's annual Ag Expo, 2) City of East Lansing Compost and Rain Barrel Sale, and 3) the City Flats in Holland, MI. In each of these rollouts, partners and colleagues were present to explain how the system worked, give demonstrations, and, in some venues, provide incentives for using the system or inquiring about it. In addition, fact sheets highlighting the core green practices were made available, interactive stormwater conservation games were hosted, and compressed souvenir sponges that advertised NECO with the name, logo, and URL printed on it were all used in the soft rollout process.

In phase two, a larger campaign was initiated in January of 2011 to advertise NECO across partner states and showcase its purpose and use. In addition to live demonstrations, other mechanisms were used to publicize the site and reach a larger audience, including brochure mailings, poster sessions at National and state conferences, webinars, a presence on social networking sites, radio and news media sites, and phone calls to environmental groups.

A four-panel glossy-colored brochure, that highlights the purpose of NECO and its mapping and social networking capabilities, was sent to 15 major libraries in key cities across the Great Lakes Basin. Letters were enclosed which requested each library to share the enclosed brochures and provide a shortcut link on their computers for their patrons to visit the NECO website.

NECO was also presented in early spring of 2011 at four different meetings with audiences totaling over 1,500 people. These included the National Water Program in Washington D.C, Michigan State University's ANR Week Presidential Luncheon, Michigan State University Specialist Forum, and the Michigan Water Environment Association. NECO was again highlighted during the 2011 Ag Expo, attracting over 1,000 participants.

Partners in Racine, WI initiated their rollout in early fall of 2011 that informed approximately 30 direct participants and was webcast live to GIS classes in several satellite technical colleges. IWR and NECO were also featured on *Greening of the Great Lakes*, a weekly News/Talk radio program out of Detroit, MI.

An upcoming three-state sponsored webinar, with Ohio, Wisconsin and Michigan, in May of 2012 will highlight tools that can be used to address climate change. NECO will be featured along with some tools developed by NOAA. It is anticipated that 300 people will attend the webinar. In the Great Lakes region an article is being developed by the *Great Lakes Echo*, a web based news site, which features environmental news across the Great Lakes basin. Finally, NECO will be presented at the NIFA (National Institute of Food and Agriculture) National Water meeting in Portland, OR in May of 2012.

Project Results

IWR used a variety of indicators to track and monitor program success including: interviews with partner groups, measuring types of participation and interaction on the site, user statistics, and number of practices adopted, in addition to many other indicators mined through server-side data collection.

User and Use Statistics

User statistics provides a good overview of the engaged audience, while the use statistics help to illustrate the interactions of the users on the website. Together, this information can be used to examine the growth and potential sustainability of the site. The target audiences for the NECO project were environmental groups and organizations, home owners, and businesses. The NECO website has approximately 200 registered users, of which 70% are residential, 23% environmental groups, and 7% businesses. While a greater proportion of users are individual home owners, it is worth noting there has been a steady increase in both the number of environmental groups/organizations and businesses using the site from 10% to 23.4% and 1% to 7%, respectively (Figure 1). This may be attributed to the unique value the NECO website provides to these types of user groups. While home owners are likely to only install 1-3 practices, organizations may install hundreds or thousands over time, and this inherent long term use provides a unique value to these types of groups.

Since the beginning of the project there has been an upward trend in the amount of new registered users per 5 month period, up 44% from 1 year ago (Figure 2). This increase is also seen in the total number of registered users. At the current rate of growth we anticipate close to 350 registered users by the first quarter of 2013. Users have heard about and visited the site through a number of avenues. The three most popular ways people have come to know about the website are: 1) hearing

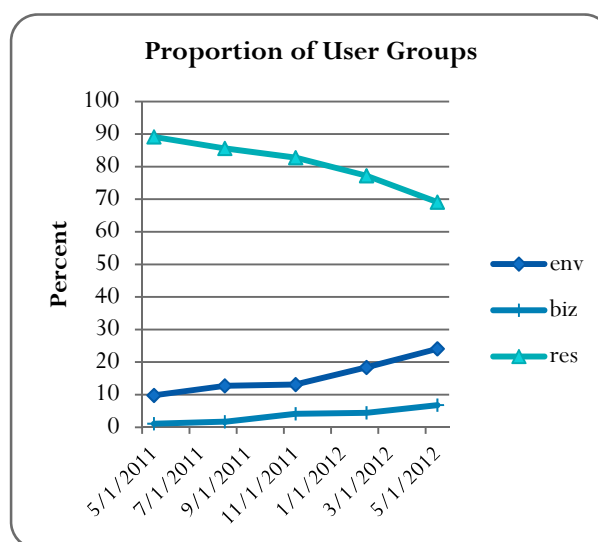


FIGURE 1

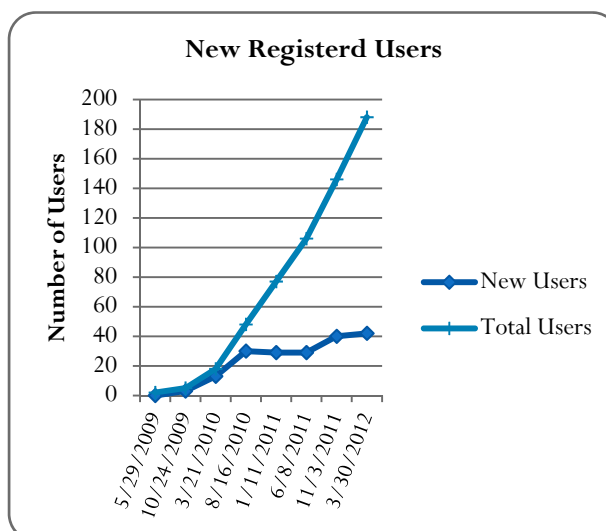


FIGURE 2

about it from an organization involved with the NECO project, 2) through a friend, or 3) via a presentation.

One of the barriers to successful implementation that IWR noted early in the project was low participation. This can often be attributed to lack of user comprehension. IWR used formal user evaluation workshops in the partner's communities to identify potential design problems and to refine the interface based on user feedback. As a result, surveys showed that users felt the site was organized, useful, and informative when asked to rate a series of words describing NECO.

IWR examined registered users and a combination of registered and non-registered users to determine how successful the website has been at attracting repeat visitors. Repeat visitors are a good indicator of how useful and valuable the site is to the audience. Data showed that approximately 20% of registered users returned to the site, while the combination of registered and non-registered users produced around 32% return visits. This is slightly above a recent average conducted by Cosemindspring.com³ on 60 websites from the US (Fortune 2000 companies, small business, and non profits, for example) where the average returning visitor rate was 28%. Non registered users may use the site to collect information about green practices or utilize the mapping interface which does not require the user to register with a username and login.

Green Practices and Environmental Impacts

Environmental benefits are often complicated to assess having influence from a variety of parameters. Often there may not be any mechanism in place to capture and summarize the targeted data. This makes it difficult to report any quantitative change. To address this IWR developed a reporting function that summarized the calculated beneficial impacts from green practices installed across the basin. This reporting system is the first and only system currently available that summarizes the amount of water managed, as well as the reductions made to sediment, phosphorus, nitrogen, and fecal coliform across the Great Lakes Basin. The data can be aggregated into watersheds, or custom groups, or reported by individual practice.

During the project users logged over 1,000 practices into NECO. The vast majority of these practices were rain barrels, accounting for 79% of the total. These were followed by rain gardens at 18%, porous pavement at a little over 1%, and green roofs and other types at just under 1% each. We believe the high volumes of rain barrels are attributed to the ease of installation, utility, and affordability.

All of the core practices in NECO focus on capturing or slowing stormwater. Altered landscapes and increased impervious surfaces have increased stormwater runoff leading to degraded water quality in streams that feed the Great Lakes. The negative impacts include but are not limited to increased algal blooms from nutrients carried off lawns, and degraded fish habitat from sedimentation and stream flashing. Nearly 62.5 million gallons of water are currently being managed across the Great Lakes Basin by practices registered through NECO. That amount of water can be translated to reductions in sediment, nutrients, and fecal coliform using engineering curve numbers and the Long Term Hydrologic Impact Analysis (L-THIA) Tool developed out of Purdue University. The estimated pollutant reductions for practices registered through NECO are: 952 lbs of nitrogen, 298 lbs of phosphorus, 10.7 tons of suspended sediment, and 472.7 billion colonies of fecal coliform. By reducing these pollutants and moving toward a more natural pre-urbanized hydrology, there is an increased likelihood of reduced algal blooms, improved fish habitat, and improved ecological health throughout the Great Lakes basin.

Impacts on Organizational Partners

In the winter of 2012, interviews were conducted with three organizational representatives to understand the effectiveness of the Networked-Neighborhood Project in meeting its goals. The interviews were with our three main partners, and each was asked to reflect on the meaning of the project to them, their use of the NECO tool and related information by their organization. A set of questions were also asked about their understanding of the environmental problems they face.

³ <http://www.cosemindspring.com/en/Topics/Marketing/Search%20Engine%20Marketing.aspx>

Interview questions were focused around three broad areas:

- a) What is your perspective on the NECO Project?
- b) What goals are your organization attempting to achieve and what are the barriers to achieving them?
- c) How has NECO been (or not been) useful in helping your organization achieve those goals?

A) PERSPECTIVES ON THE NETWORKED-NEIGHBORHOOD PROJECT

All three interviewees communicated that the NECO project had, at its core, a positive element of communication and community building. They saw the website as a means by which to report and visualize what other water conservation groups in their area were doing and to foster communication between these groups (and other concerned individuals). Although all three saw this communication element as being central, they had different visions for what the end-goal of that communication would be. For one person, NECO was primarily a way to report data and statistics about water conservation efforts in his area. Another saw this communication as a way to build partnership activities between organizations, and the third person viewed it as a tool to engage other communities to adopt environmental stewardship behaviors.

B) PARTNER ORGANIZATIONS NEEDS

All three of these organizations focused on water conservation and, in particular, mentioned having these environmental issues in common: runoff (stormwater, agricultural, urban, and airport), algae, sedimentation, groundwater protection, and general water quality. Some of the common impacts of these environmental concerns were reduced fishing industry and tourism, public health risks, water scarcity, and closed beaches. Similarly, all three organizational representatives mentioned the use of rain barrels, rain gardens, and education as a primary solution to these issues. Just as the proposed solutions were similar, the barriers to implementing these behaviors were also similar: lack of knowledge/awareness, lack of time/labor capacity (not enough staff/ time), and budget restrictions.

C) HOW NECO HAS IMPACTED ORGANIZATIONS

When asked how NECO had been useful to their work, responses included how data pulled from the NECO website had been a key factor in some presentations and promotional materials. NECO was also useful in helping to identify communities where the organization's services had not been adequately promoted and/or utilized. When asked specifically about how NECO helped change environmental behaviors and assist in data collection, all three interviewees said that, as yet, they hadn't seen the NECO project impact environmental stewardship behavior practices in their region, although most believed that NECO had that potential. They did see ways in which NECO had made data collection and communication easier, as well as being able to see that information geographically.

D) OTHER NOTED ISSUES

All three mentioned similar difficulties that hampered the usefulness of the NECO website as a data collection tool. Uploading information in batches was difficult, time-consuming, and didn't always work. Because of these barriers, organizations either a) weren't updating their information regularly or b) were using other platforms (such as Google Maps) to accomplish similar types of goals. Two of the three said explicitly that the NECO website was too "tech savvy" for most of their employees and, due to labor shortage, updating NECO was no longer a priority.

While all three organizations mentioned difficulty using the batch upload function, two of the three continued to use the individual practice upload function through all of 2011 and the beginning of 2012. The batch function was tested during the user evaluation workshops and reported to be easy to use. However, sometime after development users began upgrading their Microsoft Office Suite to Office 2007. In the new office 2007, the requirements for XML schemas were different. This caused the templates that were provided to no longer work. The task would fail halfway through its execution, requiring project partners to input practices one at a time or not at all. This problem was not brought to the attention of IWR until later in the project, either because users assumed that they were not technically savvy enough to figure it out, or because their failure to batch upload occurred near the end of the project. The development team is now working on creating a new template that can be used for Office 2007.

Overall, the interviews indicated that the NECO website has, to some degree, been successful in fostering communication and data sharing among these conservation groups by encouraging them to upload data to the site (particularly data about rain barrels). The uploading process, however, is perceived by partner organizations to be difficult and time-consuming. The information from the NECO website, while being used in presentations and publications, has not yet had a visible, marked impact on environmental stewardship behaviors in the Great Lakes region, and NECO has not yet been able to significantly help an organization change desired behaviors in their communities.

Survey Results

In winter 2012, IWR sent an invitation to participate in an online survey to approximately 2,000 potential users of NECO, drawing on lists from partner organizations, and internal mailing lists. These contacts were seen as either the most likely group to be the initial users of NECO, or had been invited to participate in NECO in the past. There were 647 usable responses to the survey. Of this group, only 45 (7%) could recall having heard about the NECO website, and of those only 30 had visited the NECO website (4.6% of total respondents). For those users who had visited NECO, their opinion of the site was mostly positive. They seemed to find the site easy to use, and useful overall (Figure 3). This matches previous usability tests conducted earlier in the development of the site.

In terms of which features seemed to be the most salient for people in terms of their use, the mapping tool and photos of practices were marked as highly valuable, while interaction with other users through forums of Facebook posting was seen as less valuable (Figure 4). It is hypothesized that NECO's services by default target home owners (30+ years of age according to Economists' Outlook Blog⁴) who are able to install a green practice on their property. Research has also shown that on average 52% of Internet users from age 30-65+ use social networking sites such as Facebook, as compared to 86% from age 18-29 (Pew Internet⁵). As younger audiences enter the work force and become homeowners they are likely to see a greater value in social forums such as Facebook since it has been highly integrated in their daily lives.

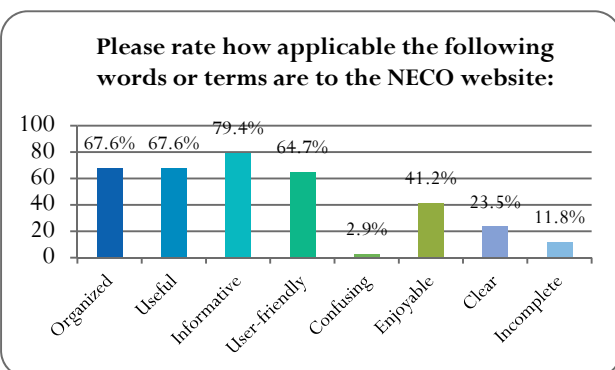


FIGURE 3

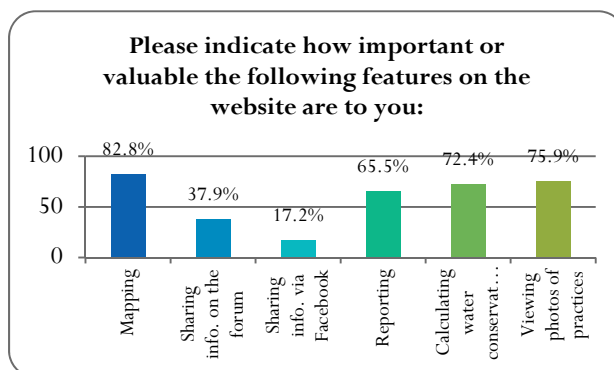


FIGURE 4

Those who used NECO also indicated that their activity on the site changed their perceptions about green practices. Of people who used the site, 72.4% either agreed or strongly agreed that they were more aware of green practices in their neighborhood, and 69% either agreed or strongly agreed that they were more motivated to add a green practice to their property after using NECO (Figure 5). Additionally, 70% agreed they were more knowledgeable about green practices after viewing NECO, and 85% said they were likely to install a green practice in the future (Figure 6).

Results for the overall sample of users showed high levels of energy and efficacy around stormwater conservation issues. The following trends were identified among the responses. There were no meaningful differences between people who had visited NECO and those who didn't. Efficacy regarding green practices was high for this group. Nearly 81% agreed that installing a green practice could improve the health of the Great Lakes, and 91% believed installing a green practice could help reduce pollution in their watershed (Figures 7 and 8).

⁴ <http://economistsoutlook.blogs.realtor.org/2011/03/07/median-age-of-home-buyers-2001-2010/>

⁵ <http://www.pewinternet.org/Commentary/2012/March/Pew-Internet-Social-Networking-full-detail.aspx>

I am motivated to adopt green practices.

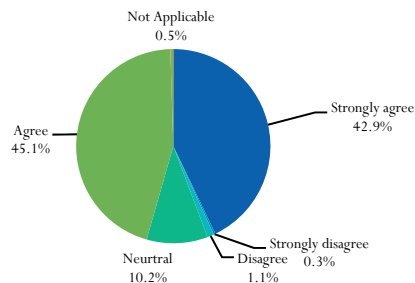


FIGURE 5

I am likely to install a green practice in the future.

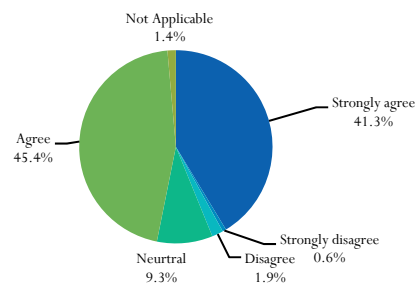


FIGURE 6

Intalling a green practice on my property will have an impact on reducing pollution in the Great Lakes.

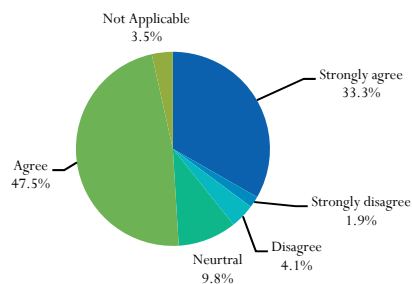


FIGURE 7

Intalling a green practice on my property will have an impact on reducing pollution in my watershed.

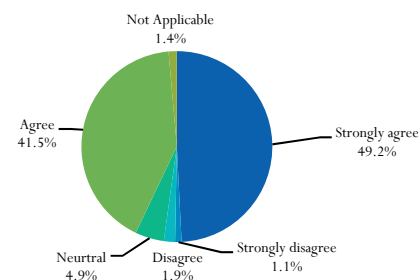


FIGURE 8

In general, respondents had strong beliefs that they could affect water quality issues (Figure 9), and that a link exists between stormwater management and water quality (Figure 10). Respondents also saw the health of the Great Lakes as a high level priority (Figure 11), which was not surprising given that many of them self-identified with water conservation organizations.

I know proven strategies I can apply as an individual to prevent stormwater runoff.

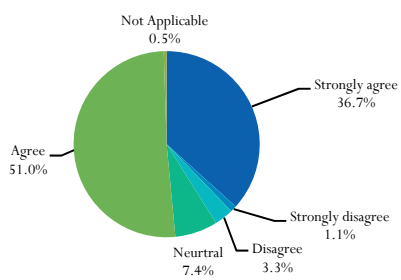


FIGURE 9

There is a strong link between storm water conservation/management and improved water quality.

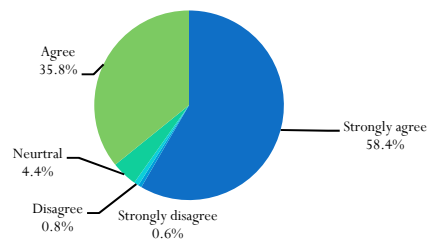


FIGURE 10

Part of this belief is likely related to their past activities. Of our sample, 78% had installed a green practice in the past, 59% saw themselves as “somewhat active” in stormwater conservation/management, and 20% as “extremely active”.

Questions regarding sources of information for water quality showed some surprising trends. Online communication was the most frequently cited source of

The health of the Great Lakes is one of my top priorities.

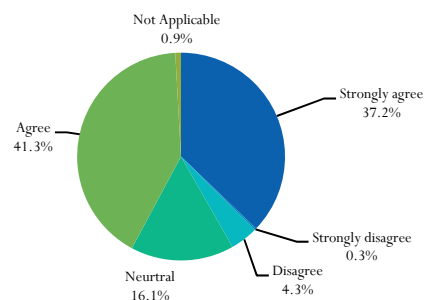


FIGURE 11

environmental news (Figure 12). Newspaper was the strongest of the mass media news sources, even though environmental coverage in mainstream news has been on the decline. Social media was not seen as an important source, which is likely related to the age demographic of this sample, which was older than a typical social media audience. A sample of younger information consumers might show different trends according to Pew reports on more general information consumption⁶.

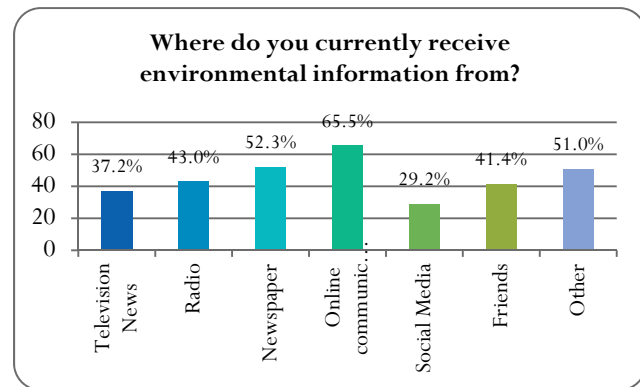


FIGURE 12

In terms of intention to either use NECO or engage in stormwater management in the future, respondents were generally very positive (Figure 13). Even those who hadn't used NECO indicated they would like to use it in the future and would recommend it to a friend (Figure 14). However, since the survey was conducted there has not been a large increase in new users, which is an indication of the difficulty of maintaining attention in a media-overloaded environment.

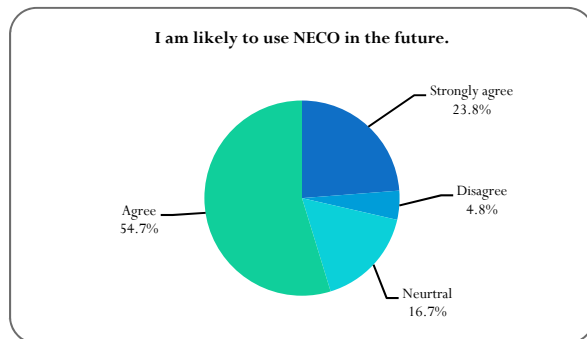


FIGURE 13

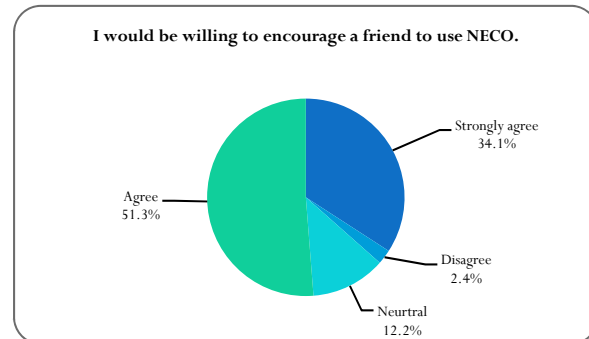


FIGURE 14

In open-ended questions regarding perceived barriers to implementing green practices, there were several consistent themes regarding what people saw as hindering widespread adoption of these techniques.

- **Cost:** this was the most consistently mentioned issue, with cost being considered both in terms of materials and time.
- **Living situation:** another common theme were limits on changing their property, either due to zoning regulations or because the person was renting and didn't have rights to install practices.
- **Knowledge:** this was expressed in several ways, but usually vaguely. About 20% of responses included knowledge as a barrier, without many specifics about the type of knowledge missing.
- **Availability of materials:** many respondents felt that key materials like pavers and rain barrels were not widely available.
- **Age:** several respondents mentioned they were elderly, or ill, and couldn't install practices on their own.

Other issues included disagreements with family members about installing practices, or concerns that an installed practice would negatively affect the aesthetics of the home. Many people mentioned that they lived on lots, or in

⁶ <http://pewinternet.org/Reports/2011/Local-news.aspx>

situations where runoff was not a problem. A minority of respondents mentioned that their efforts would be marginal compared to runoff from commercial properties.

Lessons from survey and moving forward

The survey indicates that a large group of people are interested in being involved in stormwater management and conservation, and feel they are both able and likely to install those practices in the future.

Given this capacity for involvement, why haven't levels of participation on NECO been as high as might be expected? Less than 10% of the sample had heard of the site, and participation, though active, has been exclusive to relatively few people. Those using the site reported a positive experience, and even those who haven't used the site reported that they are likely to in the future.

There are several possible reasons for the incongruity between the potential for involvement and the participation on NECO.

MARKETING – In light of the relatively small number of people who had heard of NECO, it is suspected that the marketing strategy used was not successful. The project was largely dependent on partner organizations introducing NECO to their members and surrounding community, but that strategy had not been fruitful. To move this site forward, there needs to be a stronger effort in marketing the site to potential users, and encouraging a broader awareness of the site amongst this potential community.

KNOWLEDGE GAP – In the survey, only a few people reported lack of knowledge about how to install a green practice, and in fact many had a high belief in their own ability to install one. Since a knowledge gap does not likely exist with this group, it may be beneficial to include a different audience who needs more guidance in stormwater management.

RICH ALTERNATIVES – Given that people reported a variety of sources for obtaining stormwater conservation information, it could be that NECO is competing with a large field of information and interaction sources. In many sites, this resolves itself over time as the user base grows and attracts new members. For most sites, however, it's a constant challenge to attract critical mass and differentiate from a large set of competing services. Even outside of the conservation area, NECO is competing for attention with the other online services that potential members use or consume including newspapers, social media sites, and email. Any marketing campaign should focus on what makes NECO unique amongst the alternatives for people's attention in the current media environment.

Recommendations

Overall IWR feels the project team successfully met the goals of the project. However, there are several recommendations that could be used to improve the outcome of this or similar type projects. Partnering organizations played a key role in establishing adoption of the system. IWR recommends that future projects have additional partners funded in other areas in the Great Lakes basin to provide a more uniform initial coverage and increase the potential for adoption. Although partners played a key role in developing clusters of use for NECO their recruitment of new users to the system was less than anticipated. It is recommended that a greater amount of energy be put into other marketing strategies, or to hire a marketing firm separately to help recruit new users. IWR firmly believes that the site will continue to grow and become more widely adopted; however this process could have been expedited with additional marketing.

Data collected during the project indicated that sharing information through Facebook was the least valuable feature in NECO. It is hypothesized that this is related in part to the age of the audience and will change slightly over time. Unfortunately, the development team was not able to integrate Facebook into NECO as it had hoped, and recommends that a dedicated programmer be used to work specifically with the Facebook programming interface; as it changed frequently during development hindering some of its intended integration. It is also believed that the true value of incorporating Facebook type applications is not necessarily for the user but for the potential ease of sharing

the action of installing a practice with friends, keeping the idea of stormwater conservation practices active in the thoughts of potential users. In addition, it is worth noting that a dedicated person available for updating the Facebook page regularly is critical to attracting Facebook followers.

Lastly, it is highly recommended that a user evaluation workshop process similar to what was described in this report be used to help guide the development of the interface. The development team used a user driven design strategy that proved to be successful according to the users surveyed. The resulting product will provide a positive experience for the user and encourage repeat visits and referrals.

Developing Advanced Modeling Tools for Red Cedar Watershed Planning

Basic Information

Title:	Developing Advanced Modeling Tools for Red Cedar Watershed Planning
Project Number:	2011MI187B
Start Date:	3/1/2011
End Date:	2/28/2012
Funding Source:	104B
Congressional District:	8
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Models, Nutrients
Descriptors:	None
Principal Investigators:	Yi Shi, Phanikumar S Mantha

Publications

There are no publications.

Title: Developing Advanced Modeling Tools for Red Cedar Watershed Planning

Project Number: 2011MI187B

Start Date: 3/1/2011

End Date: 2/29/2012

Funding Source: USGS (“104B”)

Congressional District: eighth

Research Category: Climate and Hydrologic Processes

Focus Categories: HYDROL, MOD, WQN

Descriptors: Hydrology, Water Quantity, Ground water, Surface water

Primary PI: Dr. Mantha Phanikumar, Associate Professor, CEE, Michigan State, A130
Engineering Research Complex, East Lansing, MI 48824, phani@msu.edu, 517-432-0851; Dr. Yi Shi, Institute for Water Research (IWR)

Project Class: Research

Introduction

Hydrologic models are increasingly being used to simulate future scenario in the presence of significant uncertainty (e.g. the impacts of climate and/or land use changes on hydrology). Process-based, distributed hydrologic models, which are based on the conservation principles of mass, momentum and energy, may be better suited to predict future scenario and to quantify the impacts of natural and anthropogenic influences on water resources. The applicability of such models to large watersheds continues to be a challenge due to the heavy computational demands. We recently developed a distributed hydrologic model PAWS (Process-based Addaptive Watershed Simulator, Shen and Phanikumar, 2010) that solves the governing equations for all flow domains efficiently. The model uses a stable and computationally efficient approach for surface - subsurface coupling that makes the model suitable for large-scale applications. We recently extended the functionality of the PAWS model in two important ways: (1) added a comprehensive vegetation module to the by coupling the functionality of the Community Land Model (CLM version 4.0, Oleson et al., 2010) with the flow modules in PAWS and (2) added a lowland storage module to model the effects of wetlands on the hydrology. The PAWS model was tested extensively using analytical solutions, experimental data, and solutions based on fully three-dimensional models.

DEM-based flow direction algorithms are widely used in GIS-based hydrologic models. But the most commonly used algorithm such as D8 (O'Callaghan and Mark, 1984) contains systematic errors. Despite many efforts such as random eight-node algorithm (Fairfield and Leymarie, 1991), multiple flow direction algorithms (Quinn et al., 1991; Freeman, 1991) and Dinf algorithm (Tarbotan, 1997), none of them consider or utilize the physical laws that govern water movement as a fluid through the landscape. These algorithms oversimplify water movement and often treat water as a solid instead of a fluid moving through the landscape. In this research, we develop and apply a new method for the representation and calculation of flow direction based on mathematical principles and physical laws that govern water movement through the landscape.

The objective of this research is to test the performance of the (PAWS + CLM) model, by applying it to the Red Cedar River (RCR) watershed in Michigan and also develop and apply the new DEM-based flow direction algorithm.

Project Objectives

1. Apply the latest version of the (PAWS+CLM) model with a comprehensive vegetation module and lowland storage modules to describe the hydrology of the Red Cedar River watershed
2. Test the model for its ability to describe both surface and subsurface (including vadose zone and groundwater) processes
3. Develop the new DEM-based flow direction algorithm and apply it to selected DEM data sample sets

Methods

Major hydrologic processes described by PAWS include overland flow, channel flow, evapotranspiration (ET), depression storage and infiltration, and sub-surface processes including vadose zone and groundwater flow processes based on structured grids. Rivers can be discretized with variable spatial step sizes. Exchange fluxes from land grid to river cell grid are computed on the river cells and transferred to intersecting land cells. This strategy allows river and land domains to be discretized independently. Within each land cell, sub-grid heterogeneity is modeled using a mosaic approach. Depending on the grid size, a cell may possess a mixture of land use/land cover types. Land use data are re-classified into model classes which are represented by several generic plant types (called plant functional types or PFTs). Depending on the climatic conditions, a layer of snow, quantified by the Snow Water Equivalent (SWE) and snow cover fraction, may exist on the ground. One soil column is modeled for each grid cell. The unconfined aquifer can exchange water and energy with the soil column. Water can percolate further down to deeper aquifers via a layer of aquitard and contribute to river water through river bed materials. More details of the model can be found in Shen and Phanikumar (2010). The original version of PAWS included a simple growth cycle formulation for vegetation. (PAWS +CLM) has the ability to describe vegetation processes in much more detail. Land-based climatic observations are passed as forcing data from PAWS to CLM. The soil hydrology and river routing routines in CLM are replaced by the corresponding procedures in PAWS. Soil moisture states are therefore unaltered in CLM except due to snowmelt and freeze-thaw phase change. Soil/snow temperatures are updated by solving the soil heat conduction equation. The soil hydrology module in CLM is replaced by the modules in PAWS, which solve the Richards equation together with ET, groundwater flow and runoff based on a large-scale coupling scheme proposed in Shen and Phanikumar (2010). Since the soil water flow processes are primarily computed in PAWS, the (PAWS+CLM) model uses the van Genuchten formulation for soil water retention relationships as the original PAWS model. The soils characterizations are derived from the SSURGO database. The soil resistances to evaporation are reformulated according to the original PAWS model.

We used a 900 m x 900 m grid for the computations. Daily or sub-daily weather data were obtained from different sources including the National Climatic Data Center and the Enviro-Weather web page. The locations of the stations are shown in Figure 1. The National Elevation

Dataset (30 m resolution NED) was used for the elevation of the land grid. The IFMAP land use land cover data (30 m resolution) formed the basis for the land use information (Figure 2). SSURGO data were used to provide initial values for the soil properties. Eight major rivers from the National Hydrography Dataset (NHD) were manually selected as the modeled river network. Two layers are used for the groundwater domain - the upper layer is the glacial deposit, taken as the unconfined aquifer while the lower layer is the bedrock, taken as the confined aquifer. Layer thicknesses and hydraulic conductivity data were obtained from the Michigan Wellogenic database (GWIM, 2006).

In the study of fluid dynamics, we often consider that fluids form a continuum wherein the motion of individual particles is not traced. The focus is on a control volume, a fixed frame in space through which the fluid passes. This is also called the Eulerian view of motion. In the proposed method, this view is adopted and every DEM cell is treated as a control volume. The assumption is that water flows through the saturated DEM surface, so Darcy's law can be applied for the water flow. One implication of this new method is that only four direct neighboring cells (directly above, below and directly left and right) instead of eight for every DEM cell are considered when the water flow is modeled. The four diagonal cells are not considered because mathematically the common area between every DEM cell and its diagonal neighboring cell is 0, so that there is no possible flow between them. This forms the foundation of the new algorithm. The flow direction as a vector is then calculated as sum of all 4 vectors going from the center cell to 4 direct neighboring cells. The magnitudes of 4 vectors are determined by their respective slopes. This algorithm is implemented in C++ and applied to both rugged terrain in New Mexico and flat terrain in Michigan. The results are shown in the next section.

Results

We applied the (PAWS+CLM) model to the Red Cedar River (RCR) watershed in Michigan and model outputs are compared to different types of data to understand the ability of the new model to describe key hydrologic processes in this watershed. Figure 1 shows a map of Michigan, the Grand River watershed as well as the RCR sub-watershed.

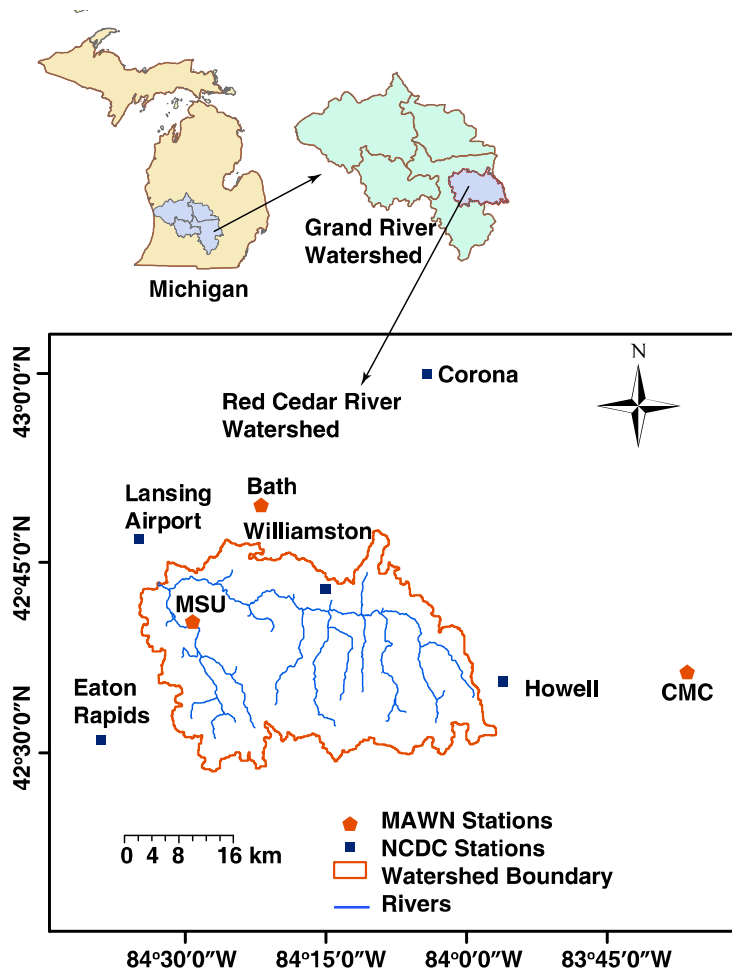
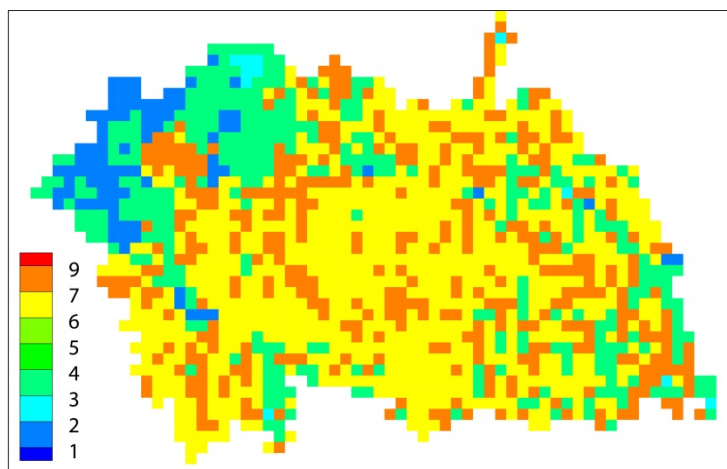


Figure 1. Map of Michigan showing the Red Cedar River watershed



Model LULC Classes (Major):
 9= Forage Crops, 8 = Bare Soil, 7 = Row Crops, 6 = Bush & Shrub, 5 = Evergreen Forest
 4 = Deciduous Forest, 3 = Herbaceous Open Land, 2 = Urban or Industrial, 1 = Water

Figure 2. Map of major (reclassified) land use categories in the RCR model grid cells.

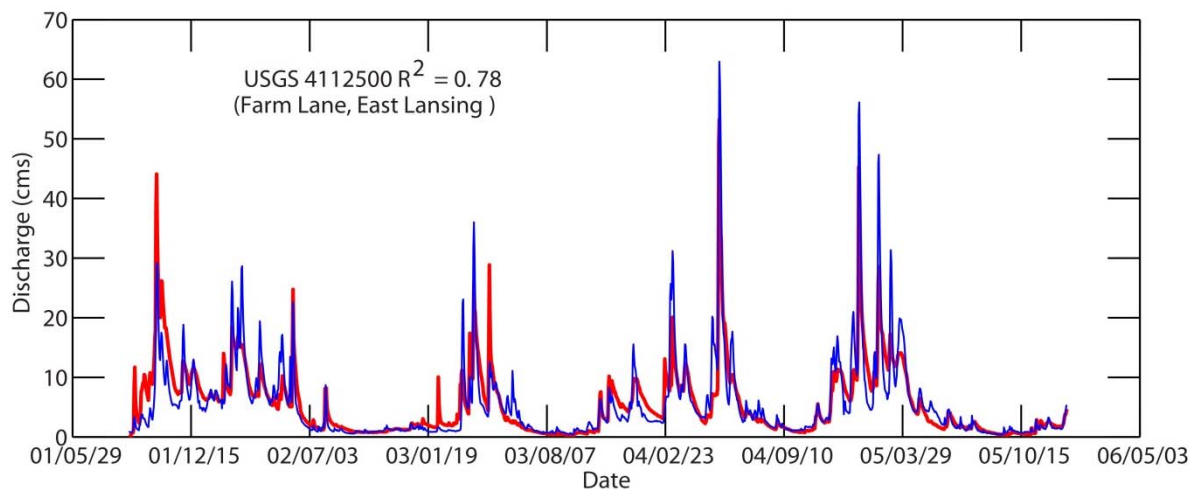


Figure 3. Comparison of observed (USGS, blue line) and modeled (red line) streamflows at the Farm Lane gage (Time on the X-axis is in YY/MM/DD format)

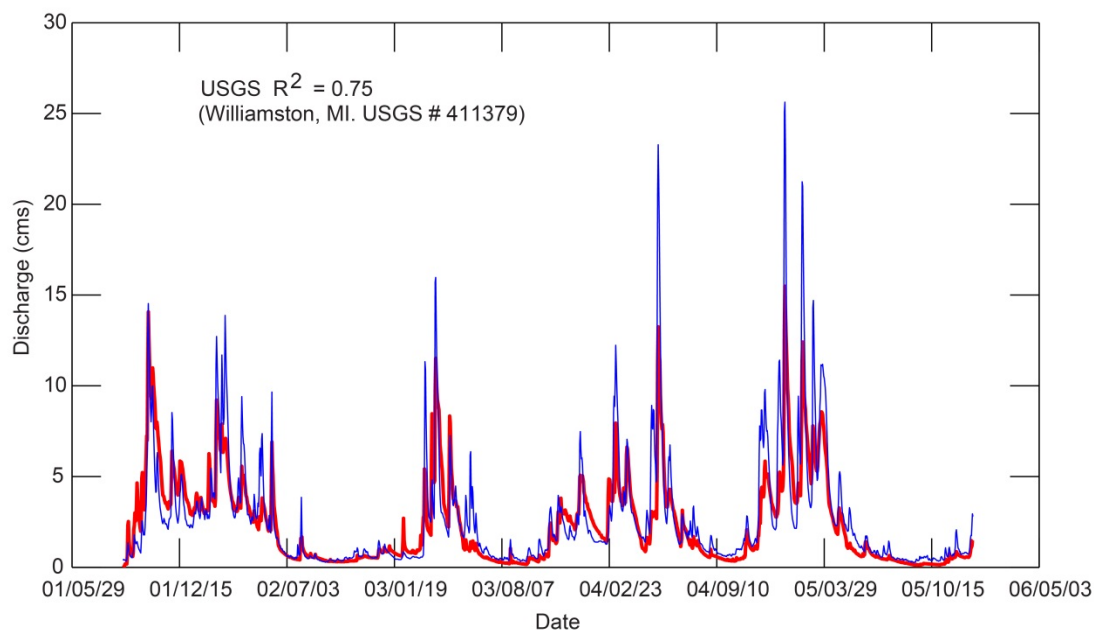


Figure 4. Comparison of observed (USGS, blue line) and modeled (red line) streamflows at the Williamston gage (Time on the X-axis is in YY/MM/DD format)

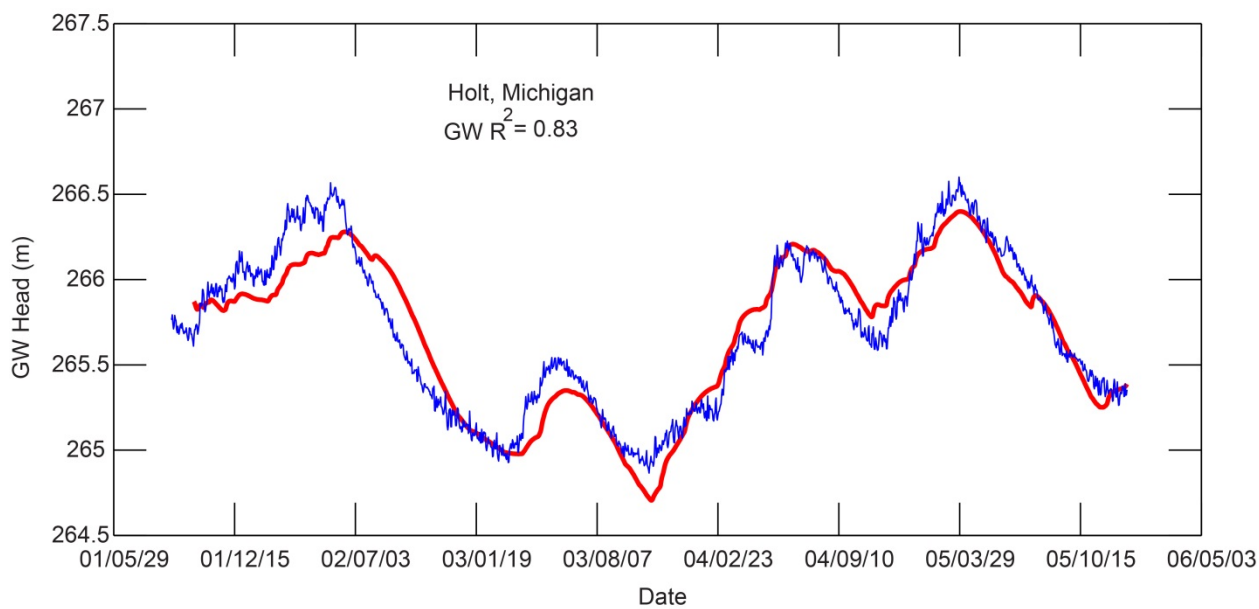


Figure 5. Comparison of observed (USGS, blue line) and modeled (red line) unsteady groundwater heads at Holt, Michigan (Time on the X-axis is in YY/MM/DD format)

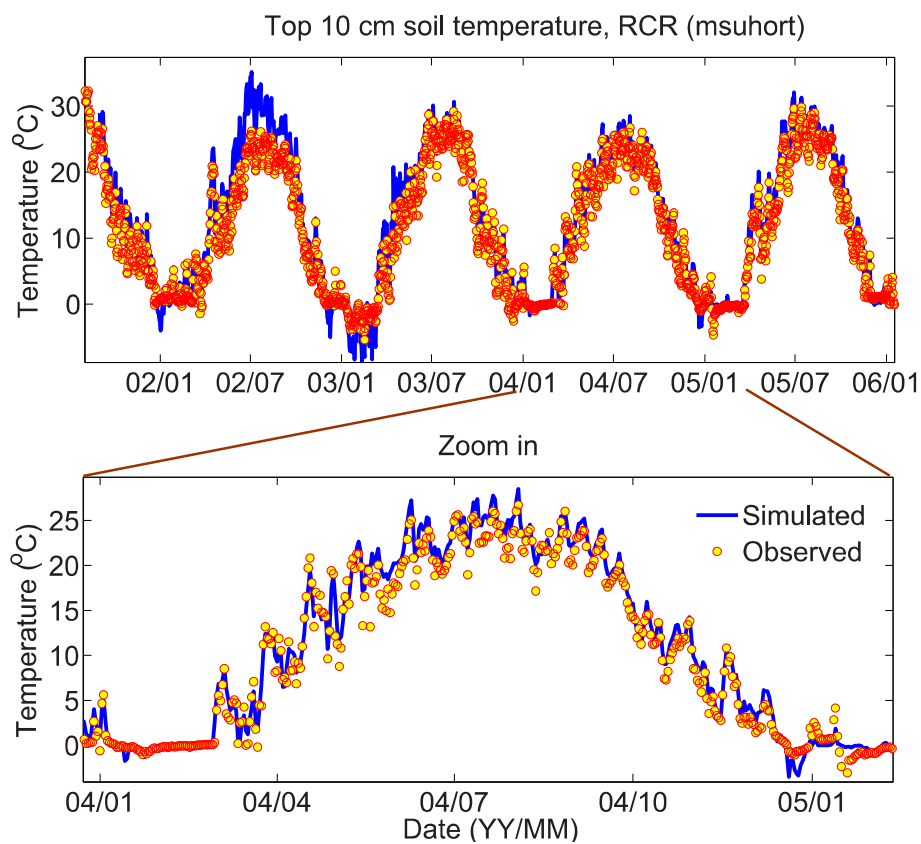


Figure 6. Comparison of observed (symbols) and modeled (blue line) soil temperature in East Lansing. Data source: Enviro-weather (<http://www.enviroweather.msu.edu/>)

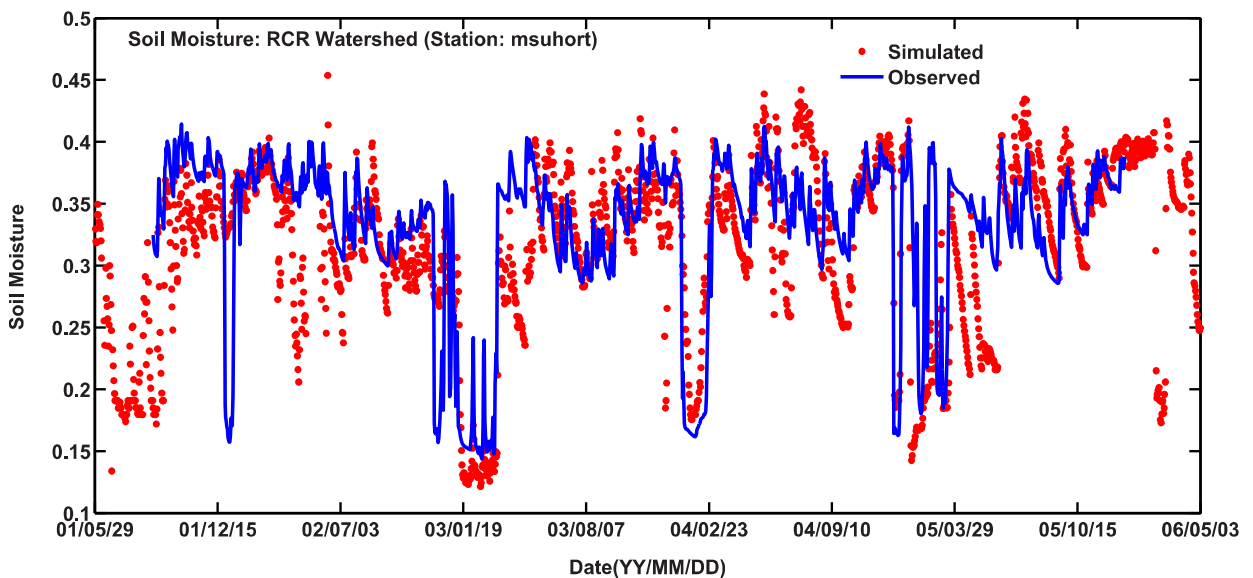
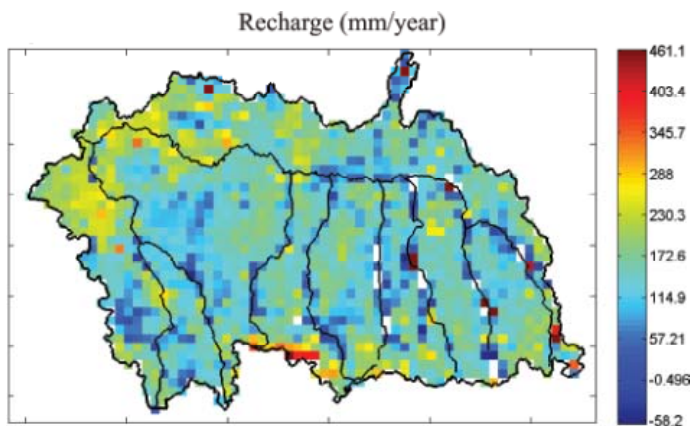


Figure 7. Comparison of observed and simulated soil moisture in East Lansing. Data source: Enviro-weather (<http://www.enviroweather.msu.edu/>)



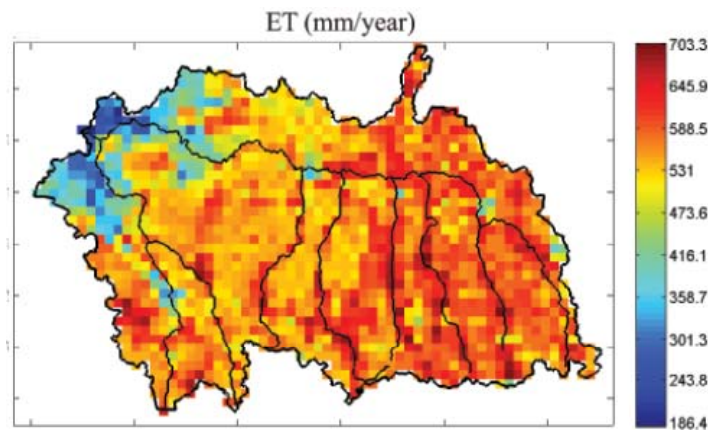


Figure 8. Spatial maps of multiple-year average (top) recharge and (bottom panel) ET for the RCR watershed.

Since the new DEM-based flow direction algorithm is a completely local raster based calculation, we can apply it to any sample area of landscape topography. Both rugged and flat terrain data samples are used to test the algorithm. The 10 meter DEM data samples are obtained from USGS for this study. Figure 9 shows the calculated flow vector on the rugged terrain sample in New Mexico. Figure 10 shows the flow vector on the flat terrain sample in Red Cedar Watershed in Michigan.

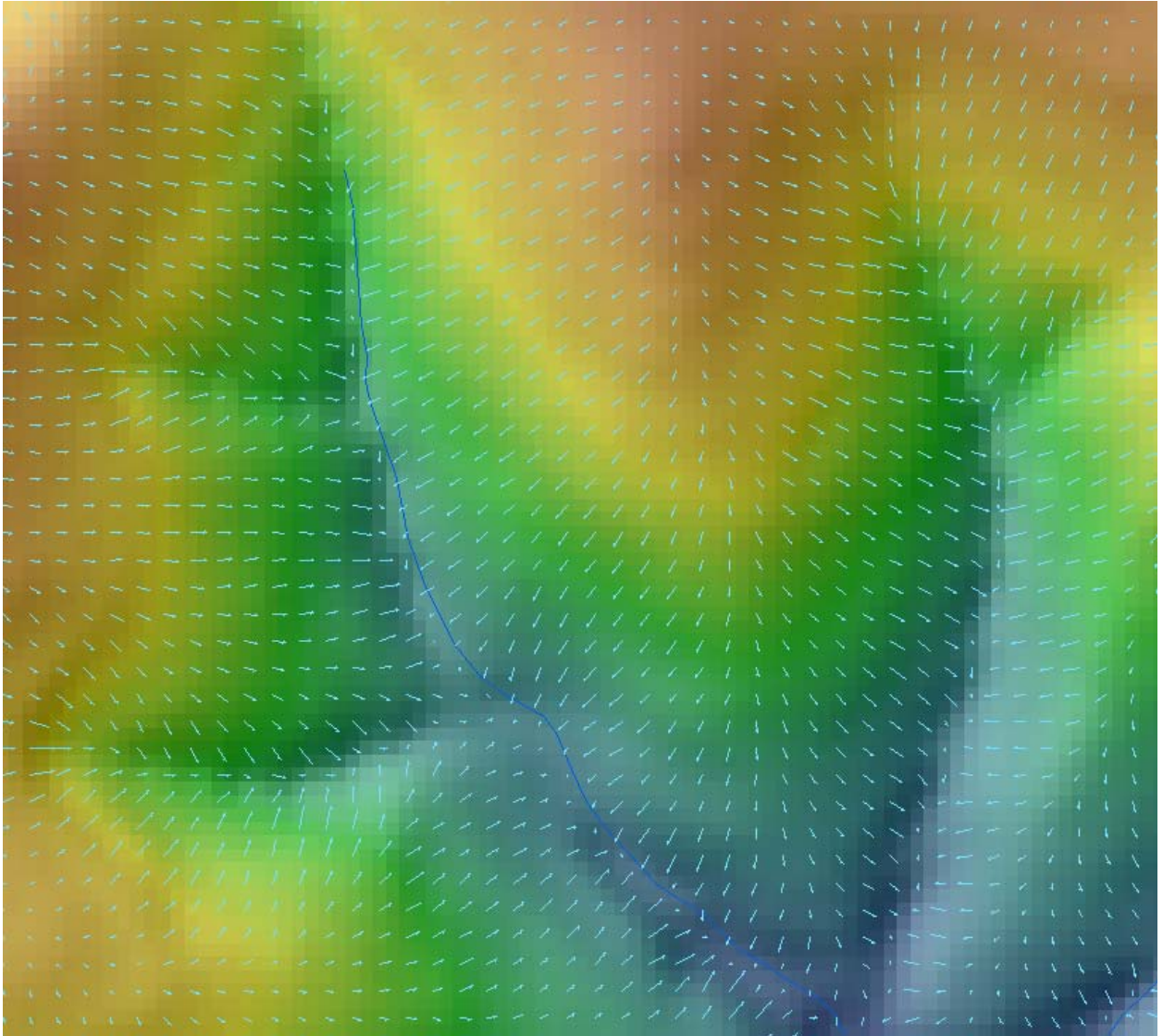


Figure 9. Flow Vector on a Rugged Terrain in NM

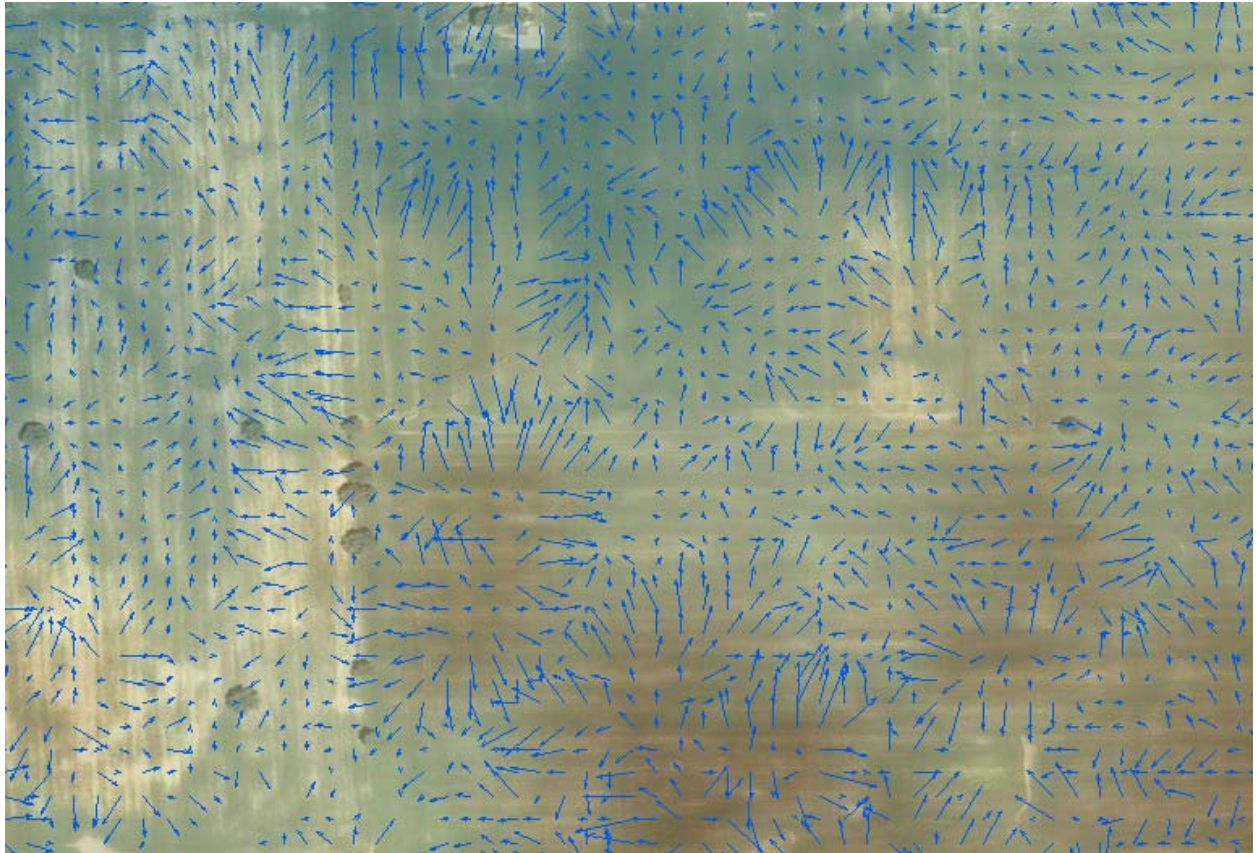


Figure 10. Flow Vector on a Flat Terrain in Red Cedar Watershed, MI

Principal Findings and Significance

The above comparisons for stream flows (Figures 3 and 4), groundwater heads (Figure 5), soil moisture and soil temperature (Figures 6 and 7) indicate that the model has the ability to describe key hydrologic (i.e., both surface and subsurface) processes in the watershed adequately. Systematic parameter estimation is expected to further improve these comparisons. We note that base flow is described particularly well in Figures 3 and 4 since subsurface processes are explicitly described in the model (Figures 5-7). The spatial maps of recharge and evapotranspiration shown in Figure 8 can be explained based on land use and soils data. Simulated ET fields are consistent with MODIS-derived ET fields (not shown in the figure). Based on these comparisons we conclude that the (PAWS+CLM) model is suitable for future climate change assessments and for watershed planning. Fate and transport models (for bacteria, sediment, nutrients) based on the flow modules in (PAWS+CLM) are currently being tested. Since the fundamental unit in PAWS is a grid-cell and not a sub-watershed, the model can be expected to provide useful information by allowing the user to easily refine grids in areas of interest (e.g., from the point of erosion / sediment transport studies).

As you can see from the figure 9, the new DEM-based flow direction algorithm works very well with rugged terrain data, the flow vector clearly follows the terrain gradient. But on the flat terrain data, the flow pattern is not easily discernible. This is due to flatness of the terrain and the

resolution of the 10 meter DEM cannot pick up the micro-topography at the field level. This suggests the utility of high resolution terrain data set such as LiDAR data.

Acknowledgements

We thank Mr. Jie Niu, graduate student, Department of Civil & Environmental Engineering, MSU and Dr. Chaopeng Shen for their contributions to this research.

References

- C. Shen and M.S. Phanikumar, A Process-Based, Distributed Hydrologic Model Based on a Large-Scale Method for Surface - Subsurface Coupling, *Advances in Water Resources*, vol. 33(12), pp. 1524 - 1541, doi: 10.1016 / j.advwatres.2010.09.002 (2010)
- Oleson, K.W., D.M. Lawrence, G.B. Bonan, M.G. Flanner, E. Kluzek, P.J. Lawrence, S. Levis, S.C. Swenson, P.E. Thornton, A. Dai, M. Decker, R. Dickinson, J. Feddema, C.L. Heald, F. Hoffman, J.-F. Lamarque, N. Mahowald, G.-Y. Niu, T. Qian, J. Randerson, S. Running, K. Sakaguchi, A. Slater, R. Stockli, A. Wang, Z.-L. Yang, Xi. Zeng, and Xu. Zeng, 2010: Technical Description of version 4.0 of the Community Land Model (CLM). NCAR Technical Note NCAR/TN-478+STR, National Center for Atmospheric Research, Boulder, CO, 257 pp.
- GWIM. State of Michigan Public Act 148 Groundwater Inventory and Mapping Project (GWIM). Technical Report. 2006.
- O'Callaghan, J. F. and D. M. Mark, (1984), "The Extraction of Drainage Networks From Digital Elevation Data," *Computer Vision, Graphics and Image Processing*, 28: 328-344.
- Fairfield, J. and P. Leymarie, (1991), Drainage Networks from Grid Digital Elevation Models, *Water Resources Research*, 27(5): 709-717.
- Freeman, T. G., (1991), Calculating Catchment Area with Divergent Flow Based on a Regular Grid, *Computers & Geosciences*, 17(3): 413-422.
- Quinn, P., K. Beven, P. Chevallier and O. Planchon, (1991), "The Prediction of Hillslope Flow Paths for Distributed Hydrological Modeling Using Digital Terrain Models," *Hydrological Processes*, 5: 59-80.
- Tarboton, D. G., (1997), A New Method for the Determination of Flow Directions and Contributing Areas in Grid Digital Elevation Models, *Water Resources Research*, 33(2): 309-319.

Interdisciplinary Water Science and Policy Modeling Workgroup

Basic Information

Title:	Interdisciplinary Water Science and Policy Modeling Workgroup
Project Number:	2011MI188B
Start Date:	3/1/2011
End Date:	2/29/2012
Funding Source:	104B
Congressional District:	8
Research Category:	Social Sciences
Focus Category:	Ecology, Models, Law, Institutions, and Policy
Descriptors:	
Principal Investigators:	Jinhua Zhao, Jon Bartholic

Publications

There are no publications.

Title: Interdisciplinary Water Science and Policy Modeling Workgroup

Project Number: 2011MI188B

Start: 03/01/11(actual)

End: 02/29/12 (estimated)

Funding Source: USGS (“104B”)

Congressional District: eighth

Research Category: Social Sciences

Focus Categories: Ecology, Models, Law, Institutions, and Policy

Descriptors:

Primary PI: Jinhua Zhao, Environmental Science And Policy Program, MSU, East Lansing, MI, jzhao@msu.edu

Project Class: Research

Introduction

Do to PI complications this project has been extended until 2/28/13. A full report will be turned in on June 1, 2013.



Building a Transforming Framework for Resilient Policy Option and Water Resource Management for Michigan and Internationally

Basic Information

Title:	Building a Transforming Framework for Resilient Policy Option and Water Resource Management for Michigan and Internationally
Project Number:	2011MI189B
Start Date:	3/1/2011
End Date:	2/28/2012
Funding Source:	104B
Congressional District:	8
Research Category:	Social Sciences
Focus Category:	Law, Institutions, and Policy, Water Quality, Water Quantity
Descriptors:	None
Principal Investigators:	Karim Maredia, Jon MacDonagh-Dumler

Publications

There are no publications.

Title: Building a Transforming Framework for Resilient Policy Options and Water Resource Management for Michigan and Internationally

Project Number: 2011MI189B

Start: 03/01/11(actual)

End: 02/29/12 (actual)

Funding Source: USGS 104(B)

Congressional District: eighth

Research Category: Social Sciences

Focus Categories: Management and Planning, Water Quality, Water Use

Descriptors: Water Management, resilience

Primary PI: Dr. Karim Maredia, Professor, Institute of International Agriculture, MSU

Project Class: Research

Introduction

Attributes of resilient water management systems in highly stressed areas are being investigated in Central and South Asia. This project has developed a working agreement with the American University of Central Asia located in Bishkek, Kyrgyzstan. In South Asia this project has focused on the resilience of development needs in northern Sri Lanka. Both of these approaches are revealing the attributes and strategies for developing a framework for resilient water management practices. This report provides further information on these initiatives.

Problem

Current water management systems in the United States are often sub-optimal in their overall performance, especially in terms of the sustainable provision and use of freshwater supplies and their ability to mitigate water quality impacts. In highly stressed areas water management systems do not have adequate resilience or the ability to withstand major disruption and adapt, and thus are unable to even maintain a status quo performance. This project has taken an international focus on two global areas with high water stress.

Central Asia: The region is very arid and it's limited water resources are dominated by two major river basins: Amu Darya (72 percent arid) and Syr Darya (89 percent arid). Both water systems are fed principally by melting snowpack and glacier waters. The seasonal cycles associated with these sources create significant challenges for managing the use of water resources for competing needs, principally agriculture and hydropower generation. Other important challenges include institutional arrangements for managing transboundary resources among the five countries of Central Asia and for transitioning those arrangements from a Soviet style of governance to democratically based ones. This project is developing a research agenda in cooperation with the American University of Central Asia.



South Asia: Although the South Asia region is endowed with a variety of water resources, availability of a consistent supply of water for human consumption and other economic needs has become a major constraint in the region. These problems are exacerbated in the face of growing demand for water with population growth, climate change, and civil and political conflicts. A visit was made to the Northern region of Sri Lanka that was severely affected by long civil war that prevailed in the country for 30 years and by the 2004 tsunami. Besides the detriments to human lives, the conflict and tsunami cause much damage to the infrastructure and deteriorated the public utility systems. Some water and irrigation networks in the region were badly damaged during war and those that survived were largely depreciated due lack of maintenance and investments for rehabilitation. The region is now in a recovery process and there are many ongoing projects funded by the government and other organizations to establish and review irrigation and water schemes to increase the supply of water.



Research Objectives

The objectives of this research are to perform an integrated national and global analysis of water management systems and publish guidance for future research based on a transforming framework.

Methodology

Central Asia: This region affords the breadth in scope for research on large scale problems in water stressed areas. The platform for developing a framework as envisaged in this project begins by collaborating with local stakeholders. Specifically, a Memorandum of Understanding (MOU) has been initiated between the Institute of Water Research at Michigan State University and the Central Asia Studies Institute at the American University of Central Asia to foster international cooperation in education and research. The following activities are being pursued:

- Exchange of materials in education and research, publications and academic information;
- Exchange of faculty and research scholars;
- Joint research and meetings for education and research;
- Creation and marketing of electronic instruction media, including credit and non-credit courses.

South Asia: Site visits and stakeholder interviews were used to investigate and collect information on the water and water management issues in the region. Reports, publication, and policy briefs pertaining to water issues in Sri Lanka were collected. Site visits were made to Thirunelveli and Kondavil Public Distribution Units and farm fields. Key stakeholder interactions included: a meeting with the Regional Manager of the National Water Supply and Drainage Board, Dr. Dushyanthi Mikunthan and other university faculty involved in water research, Government agriculture extension officers, Dr. Herath Manthirithilake head of the Sri Lanka Development Initiative at the International Water Management Institute, and farmers.



In addition, a series of water related questions were included in a preliminary agriculture informant survey conducted by the University of Jaffna in Jaffna, Kilinochchi, and Mullativu Districts in the Northern Province to collect data at village level. These questions aimed to determine water sources and usage patterns of the rural farmers and the role of self-help groups and NGOs and gender issues play in facilitating and granting access to water in an agricultural context.

Principal Findings

Central Asia: Cooperative endeavors in research, education and outreach have been identified. Funding for long-term projects are being developed. Results will be reported as these are completed.

South Asia: The stakeholder survey reveals heterogeneity across and within the districts in terms of the type of irrigation available. For instance, in the Jaffna district which is generally considered a dry region according the agro-ecological zones in Sri Lanka, rain-fed cultivation was only possible during the monsoon season (December – March). Nearly half the farmers interviewed reported using well water for crop production. Tanks, reservoirs, and dug ponds were used in places where there were more abundance in inland water and the water tables were located close to the surface. The farmers who identified water as a constraint to production mostly relied on surface water (ponds) for cultivation as the water availability declines during the months after the monsoon. Surprisingly, majority of the farmers stated that they did not find it difficult to obtain water for agriculture. Of those who experienced hardships, their main issues were due to salinity, drying, and shortage cause by over-sharing of a single well. Only a minute fraction of the informant in random clusters was members of a Water User Association that was managed by the Department of Irrigation. These associations have a marginal presence and were reported to be less than efficient in disseminating their services and the member farmers did not have a clear vision of the organizations goals and functionality. Women's participation in these associations has not been well recognized and has received very limited attention. In spite of the widespread water quality issues, only 10 percent of the farmers recognize contamination problems and they associate it with various reasons: leaching of agro-chemicals into drinking water wells located near agricultural fields, increase in alkalinity levels in irrigation water due to contamination amalgamation with household waste water, contamination of wells during flooding (salt water intrusion in coastal areas). In response to these affects farmers commonly abandon the use of these contaminated water sources, consequently multiple dug well and ponds were observed in some farm fields.

Significance

Central Asia: Climate change is severely impacting the hydrology of the region. Increasing summer temperatures place greater burdens on the water irrigation system. As a consequence the reservoirs holding snowpack and glacial melt water are depleted and at dangerously low levels during the winter impairing the ability to produce power, especially in the cold high altitude regions of Central Asia. Clearly, these problems are strongly inter-related and would benefit from greater resilience in management approaches. The platform for carrying out research on these problems is now in place.

South Asia: During the visit, the potential for future research and collaborations was explored in the area of Water Management. Scientists and researchers involved in Natural Resources Management at International Water Management Institute (IWMI, Sri Lanka) and University of Jaffna are keen to form partnerships with MSU on future projects:

- Joint proposal and concept development
- Post-doctoral research and internships
- Capacity building and training activities

Research on the above problem areas would benefit from a transforming framework in two key respects. First, the framework could guide future research with the aim of creating ecosystem-based and better integrated management approaches having more resilient capacity to adapt to major disruptions and/or changing demands from users. Second, research will be strengthened by a broader global focus that will be a key premise of such a framework.

Publication Citations

Publications will be forthcoming.



Information Transfer Program Introduction

None.

Information Dissemination and Technology Transfer Training Programs

Basic Information

Title:	Information Dissemination and Technology Transfer Training Programs
Project Number:	2011MI186B
Start Date:	3/1/2011
End Date:	2/28/2012
Funding Source:	104B
Congressional District:	8
Research Category:	Water Quality
Focus Category:	Education, Surface Water, Groundwater
Descriptors:	None
Principal Investigators:	Lois G Wolfson

Publications

1. Stepenuck, Kristine, Lois Wolfson, Barbara Liukkonen, Jerry Iles, and Timothy Grant. 2011. Volunteer Monitoring of E. coli in Streams of the Upper Midwestern United States: A Comparison of Methods. Environmental Monitoring and Assessment: Volume 174, Issue 1:625-633.
2. Wolfson, Lois. 2011. Invasive Phragmites Threatens Wetlands, Wildlife. Lake Effect, July 2011. Michigan Chapter, North American Lake Management Society. Pages: 7-8.
3. Wolfson, Lois. 2010. Harmful Algal Blooms on the Rise. 2010. Lake Effect: Vol. 2. February 2010. Michigan Chapter, North American Lake Management Society. Pages: 6,9.
4. Vigmostad, Karen. 2011. Your Lake and You (Michigan Version, 2nd edition). Edited and re-written by Lois Wolfson, Howard Wandell and Robert Sweet. North American Lake Management Society, Madison, WI. 8 pp.

Project Number:

Start: 03/01/11(actual)

End: 02/28/12 (actual)

Title: Information Dissemination and Technology Transfer Training Programs

Investigators: Lois G. Wolfson, Institute of Water Research, Michigan State University

Focus Categories: EDU, GW, SW, WQL

Congressional District: Eighth

Descriptors: Water Quality; Water Quantity, Watershed Management; Natural Shorelines; Climate Change; Interactive Web-based Systems; Exotic Species

Problem and Research Objectives

Universities have a positive reputation for providing dependable, accurate and unbiased information to its clientele and partners, by providing science-based data and research results. But, as information from multiple and unverified sources becomes increasingly accessible over the internet, it is critical that Universities continue to provide current, reliable, and readily transferable information to multiple audiences in a variety of formats that are easily understood and easily accessible. An effective information dissemination program encompasses the transfer of research-based information to a wide and often diverse audience and a variety of alternative solutions, where available, to problems being assessed. The Institute of Water Research (IWR) at Michigan State University has developed and expanded upon its information dissemination and training program to address the needs of multiple groups and individuals. The objectives of the program are to develop and present educational programs designed to increase the public's awareness, knowledge and appreciation of the water quality and quantity problems in Michigan, to stress the environmental and economic trade-offs required to solve real world water related problems, and to promote transformational education that will lead to positive changes for the environment and people of the state.

Methodology and Principal Findings

Programs are offered in a variety of formats that suit the needs of individuals and user groups, including conferences, seminars, training workshops, computer models, web-based programs, and printed material. Some programs are targeted at specific groups while others are suitable for a diverse audience. Audiences include agency personnel, watershed organizations, riparian owners, farmers, local governmental agencies, students, and University faculty. Evaluations of programs are included to assess the merit of the programs and help prioritize issue areas and programming/training needs. The following programs and findings from the programs were coordinated, developed and delivered for fiscal year 2011-2012.

Conferences

Conferences are one means for reaching a large audience and addressing key issues affecting a particular resource. A key area for Michigan's economy and quality of life are the Great Lakes. The Institute has run a Great Lakes conference for the last 21 years to present current research and discuss emerging issues relating to the management and protection of this unique and valuable resource. This year the conference focused on the partnerships that have been created to



help protect and restore the Great Lakes, and the research that has been accomplished to address critical issues. Topics included Uncertainty in the Management of Great Lakes Fisheries, Great Lakes Restoration: Perspectives from a Biodiversity Blueprint, Michigan's Asian Carp Management Plan, Dreissenid Mussels, Restoring Fish Passage for Sturgeon in Lake Michigan, Monitoring the Status and Trends of Great Lakes Coastal Wetland Health, and the Great Lakes Climate Change Science and Education Systemic Network. The IWR partnered with the Michigan Sea Grant Extension Program, MSU Department of Fisheries and Wildlife, and The Office of the Great Lakes, Michigan Department of Environmental Quality (MDEQ). The conference was a standing room only crowd attracting approximately 200 people, including state and local agency personnel, researchers and educators, environmental organizations, and interested citizens. Evaluations rated the conference very highly, and many participants indicated that they would use the information gained at the conference in their classrooms or in their work.

A second conference grew out of a new partnership among Universities, state agencies, and non-governmental organizations. The Michigan Natural Shoreline partnership is providing information and training on bio-engineering of shorelines, their benefits for reducing erosion, protecting the shoreline, and providing good habitat for aquatic species. As part of the effort, a research conference titled, "Shoreline and Shallows Conference: Modern Lakeshore Revitalization" was held and jointly sponsored by the IWR, Michigan Department of Environmental Quality, and the Michigan Natural Shoreline Partnership. The one-day technical conference focused on advanced bioengineering shoreline techniques, structural habitat, and public perceptions of natural landscapes along the lakeshore. The conference also offered CEU units to certified shoreline professionals attending the meeting. Overall, 98 people attending this first annual conference, which included a number of contractors previously certified through the MNSP's Contractor's Training program.

The third conference of FY2011 was co-sponsored by IWR. The conference's main sponsor was the Michigan Chapter, North American Lake Management Society, and the IWR was responsible for organizing one of the concurrent workshops on current lake research as well as playing a primary role in organizing the conference and helping with registration and other logistics. Approximately 80 people attended the meeting, which included a pre-conference workshop and tour.

Lake and Stream Leader's Institute Alumni Program

The IWR, in coordination with its partners and the lead organization for this program, has been instrumental in the programming and development of the Lake and Stream Leader Institute since its beginning in the early 2000s. The program focuses on the development of leadership skills and understanding of local water resource management planning and program implementation. In alternative years, an alumni session is held, and former graduates are invited to attend a more intensive course. This past summer, alumni were teamed with participants from another IWR-sponsored program on volunteer stream and *E. coli* monitoring, to discuss strategies for monitoring and lessons learned from successful and struggling volunteer monitoring programs. Included in the session was a hands-on introduction to electro-fishing as well as discharge measurements and macroinvertebrate sampling. Overall, 18 people from three different states attended the session, which was held in Michigan.



Aquatic Ecology Training

The IWR helped develop and take part in a variety of other educational programs. These included the Conservation Stewards Program, Inland Lakes Program, Clean Boats, Clean Water; Oakland County water programs, Natural Shoreline Training for Riparians, and Volunteer Stream Monitoring programs. These sessions assisted local decision makers, agency personnel, riparians and other interested citizens with tools and information concerning land and water ecosystems. IWR staff assisted in the sessions through lectures, interactive sessions, and hands-on lake and stream ecology training, including aquatic plant identification, proper monitoring protocols, and treatment options. Audience size varied and ranged from 18 to 35 people per event.

Groundwater Workshop Training

Michigan State University and IWR worked collaboratively with the Michigan Department of Environmental Quality (DEQ) to provide public groundwater supplies with the information and tools needed to move toward comprehensive drinking water protection activities. Using a variety of existing hydrogeological data, drinking water recharge areas are delineated and mapped, and then provided to local water supply operators along with susceptibility assessments unique to each supply. In August, a workshop was held in the DEQ Kalamazoo District to rollout the maps and associated drinking water protection materials. Seventy individuals representing both community and non-community water supplies attended. In December 2011, 90 individuals attended a similar training session for the DEQ Grand Rapids District. Follow-up activities with public water supply operators have continued.

Internet-Based Programs Using Decision Support Tools

A major area of emphasis for the IWR is the development of decision support systems that enable citizens to make science based informed decisions through the aid of computer models, extensive data, and visual programs. Staff employees are continually upgrading the software, incorporating new models, and writing code to enable seamless entry to other web programs such as Terra-Sever, Google Earth, and social networks. Additional funding for these initiatives is often sought through various sources. Programs worked on this fiscal year included Networked Neighborhoods for Eco-Conservation (NECO), a program that combines mapping technology and social networking to encourage the adoption of low impact practices; High Impact Targeting for identifying areas contributing the greatest erosion and/or nutrient runoff; and Water Use Reporting, a program to track the amount of water being used for irrigation. The programs are used by a variety of user groups, including agency personnel, agricultural producers, researchers, and interested citizens. The IWR also produces a periodic on-line newsletter, *The Watershed Post*. This electronic newsletter provides the most current information on Institute activities as well as general articles of interest. Contributions are made by faculty, staff, and students.

Exhibit, Demonstrations and Competitions

MSU's Ag Expo, an agricultural oriented exposition is held annually during summer to highlight the work of MSU, and each year the IWR features an educational exhibit that relates water quality to agricultural and/or home practices. This year the IWR featured the NECO project on low impact practices along with the "Mapping Your Home or Watershed" program. The exhibit



was viewed by over 1000. Additionally, IWR staff gave three presentations on Pond Management, featuring the subject areas of aquatic plants, general pond ecology, and treatment methods. The presentations drew approximately 150 people.

The IWR also participated in a variety of University-sponsored or on campus one day events that showcased the University's role in science based education. These included Grandparents' University for children and their grandparent(s); AutumnFest, sponsored by the College of Agriculture and Natural Resources for friends and alumni of MSU; FFA days, a competition for high school students in the FFA program; the Quiet Water Symposium, a one-day exhibit directed towards canoers, kayakers, and those interested in non-motorized recreational vehicles; and the Michigan Science Olympics, an event for junior and high school students from across the state. All of these programs draw hundreds to thousands of people to campus. In many cases only a portion of attendees attend the events actually run by IWR staff.

Presentations, Webinars, Seminars

A variety of presentations in the form of guest lectures, seminars and webinars were provided by IWR staff members throughout the year on issues such as watershed management, stormwater and LID practices, climate change and water quality, groundwater resources, source water protection, and indicator species for water quality testing. Staff presented for the Grand River Learning Network (35 teachers), Meridian Township Environmental Board (6 members), Michigan Rural Water Association (15 attendees), MSU Contractors and Consultants Forum (350 attendees), the Michigan Agricultural Environmental Assurance Program (10 attendees), the Lansing Kiwanis (45 participants), Science Olympiad Invitational Event (50 attendees), Lake Erie Forum (50 attendees), American Association of American Geographers (20 attendees); the Midwest Spatial Decision Support Partnerships; the Indo-US Workshop on the Critical Global Challenge; the Coastal Zone 2011 Symposium; EPA Technical Staff, Chicago; various Universities, and MSU Extension campus and field staff in Natural Resources (60 attendees). A series of webinars were also held for volunteers representing rural and underserved communities. IWR staff co-organized the four webinars and presented at one of them on the topic of Data Analysis and Interpretation.

In-house Contributors

The IWR's technology transfer program is under the direction of Principal Investigator Dr. Lois Wolfson, with several IWR personnel contributing to the project, including Dr. Jon Bartholic, Ruth Kline-Robach, Jeremiah Asher, Glen O'Neil, Stephanie Smith, and Yi Shi.

Personnel and Facilities

The Institute of Water Research maintains a variety of computer workstations and servers for its growing web based decision support systems. In addition to computer-related supplies and equipment, the IWR also has video editing and photographic equipment, color printers, and field supplies for its Information Dissemination Program. The Institute's technology transfer program is under the direction of Principal Investigator Dr. Lois Wolfson, with several Institute personnel contributing to the project, including Dr. Jon Bartholic, Director, Ruth Kline-Robach, Outreach Specialist, Stephanie Smith, Web Designer, and Jeremiah Asher, Glen O'Neill and Yi Shi, Information Technology Specialists.



Significance and Notable Achievements

By providing a wide array of science-based materials and programs in a variety of formats and targeting specific groups, the citizens of the state are more informed about key natural resources and environmental issues and are more equipped with the knowledge needed to make more informed decisions concerning water issues at local, regional and state scale. In many cases, these audiences become conduits for information transfer to others within their community or watershed, thus expanding the network of a more informed citizenry.

One notable achievement that the IWR gained was initiated nearly two years ago when staff took a prominent role in developing a phosphorus reduction campaign in the state. Over the next two years, IWR worked with member organizations to promote soil testing and best management practices to reduce phosphorus runoff. Also created was a web site portal to provide ready access to other publications, videos, and workshop materials on phosphorus. IWR staff not only named the web site, “Be Phosphorus Smart” but took a lead role in organizing and maintaining it. In 2011, new legislation regulating phosphorus fertilization on lawns passed and went into effect in January 2012. The agency responsible for handling the legislation, the Michigan Department of Agriculture and Rural Development, requested that our web portal site be used as one of two official web sites to inform citizens across the state about the new law. The site gives visibility to the University while providing a valuable service to the state of Michigan by helping to inform citizens about the regulations regarding phosphorus application and continuing to provide science-based information to keep people informed on phosphorus issues relating to water quality.

Publication Citations

- Stepenuck, Kristine, Lois Wolfson, Barbara Liukkonen, Jerry Iles, and Timothy Grant. 2011. Volunteer Monitoring of *E. coli* in Streams of the Upper Midwestern United States: A Comparison of Methods. Environmental Monitoring and Assessment: Volume 174, Issue 1:625-633.
- Wolfson, Lois. 2011. Invasive *Phragmites* Threatens Wetlands, Wildlife. Lake Effect, July 2011. Michigan Chapter, North American Lake Management Society. Pages: 7-8.
- Wolfson, Lois. 2010. Harmful Algal Blooms on the Rise. 2010. Lake Effect: Vol. 2. February 2010. Michigan Chapter, North American Lake Management Society. Pages: 6,9.
- Vigmostad, Karen. 2011. Your Lake and You (Michigan Version, 2nd edition). Edited and re-written by Lois Wolfson, Howard Wandell and Robert Sweet. North American Lake Management Society, Madison, WI. 8 pp.



USGS Summer Intern Program

None.

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	6	0	0	0	6
Masters	3	0	0	0	3
Ph.D.	0	0	0	0	0
Post-Doc.	1	0	0	0	1
Total	10	0	0	0	10

Notable Awards and Achievements

A General Agreement for International Academic Cooperation Between Michigan State University Institute of Water Research, East Lansing, MI, USA and American University of Central Asia, Central Asia Studies Institute Bishkek, Kyrgyz, Republic was signed April 9, 2012 by Lou Anna K. Simon, President of MSU and Andrew B. Wachtel, President of AUCA.